ISSN 0073-6767

Proceedings of the

Indiana Academy of Science

Volume 104 *Number 3-4*

The *PROCEEDINGS OF THE INDIANA ACADEMY OF SCIENCE* is a quarterly journal dedicated to promote scientific research and the diffusion of scientific information; to encourage communication and cooperation among scientists; and to improve education in the sciences.

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PROCEEDINGS
OF THE
INDIANA ACADEMY
OF SCIENCE

Founded 29 December 1885

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Volume 104 Number 3-4
1995

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Published at Lafayette, Indiana
March 28, 1996

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Volume 104, No. 3-4 (1995)

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FOREST VEGETATION OF THE CLIFTY CANYON NATURE PRESERVE AT CLIFTY FALLS STATE PARK, JEFFERSON COUNTY, INDIANA

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ABSTRACT: Clifty Falls State Park (CFSP), Jefferson County, Indiana, was established in 1920, and a portion of the gorge was designated as the Clifty Canyon Nature Preserve in 1980. Previous descriptions of the forests in southeastern Indiana, including Jefferson County, referred to them as beech-oak and beech-oak-maple-hickory forests. Braun (1950) sampled 80 canopy trees in CFSP and described the forest there as mixed mesophytic. The purpose of this study was to sample the forest vegetation of CFSP, especially the Clifty Canyon Nature Preserve, to determine its structure and composition. The sample totaled 1154 trees (dbh > 10 cm), representing 30 species. The most important species were *Acer saccharum, Quercus rubra, Q. muehlenbergii, Franxinus americana,* and *Tilia heterophylla.* There were 306 trees/ha with a mean basal area of 26 m/ha. Since Braun (1950) reported on canopy trees only, a subset of trees greater than 30 cm dbh was selected from the current sample for comparison with her sample. The similarity coefficient between the two samples was 61%. The CFSP forest is a mixed mesophytic forest as Braun (1950) suggested, but two significant differences exist between the two studies: Braun's (1950) diversity index (*H*) was 2.47, while it was 3.72 in the current study; Braun listed 10 canopy species, whereas 22 were found in the current study. Braun's sample may have been too small to accurately characterize the species diversity of the CFSP forest.

KEYWORDS: *Acer saccharum, Aesculus octandra,* Clifty Canyon Nature Preserve, Clifty Falls State Park, forest structure and composition, Jefferson County, Indiana, mixed mesophytic forest, *Quercus muehlenbergii,* species diversity, *Tilia heterophylla.*

INTRODUCTION

Clifty Falls State Park (CFSP) was established in 1920, but little is known about the specific structure and composition of its forest. Scott (1926) referred to the dominant vegetation type at CFSP as beech-oak, which fits with Gordon's (1936) mapping of southeastern Indiana as an oak-beech region. Based on General

Land Office surveys, Lindsey, *et al.* (1965) reported that *Fagus-Quercus-Acer-Carya,* or western mesophytic forest, was the primary pre-settlement vegetation type for southeastern Indiana. The only known quantitative survey of the forest vegetation at CFSP was that of Braun (1950). Based on a sample of 80 canopy trees, she characterized the forest as mixed mesophytic. Her data are generally cited (e.g., Petty and Jackson, 1966) as representative of the CFSP vegetation.

Lindsey, *et al.* (1969) made little mention of CFSP in their survey of potential natural areas in Indiana. Yet, in 1980, the gorge area of the park was designated as the Clifty Canyon State Nature Preserve.

The purpose of this study was to intensively sample the forest vegetation of CFSP, especially within the Clifty Canyon Nature Preserve, to determine its structure and composition. These findings were compared with Braun's (1950) data and her description of the vegetation.

DESCRIPTION OF CLIFTY CANYON NATURE PRESERVE

Clifty Falls State Park is located in Jefferson County, southeastern Indiana. The park totals 550.6 ha; the Clifty Canyon Nature Preserve, which is located within the Park, totals 72.1 ha. The gorge was formed by the cutting action of glacial melt waters. The bedrock is Ordovician to Silurian shale and limestone. Soils on the slopes are predominantly Eden-Caneyville and Grayford (Nickell, 1985). Slopes range from 12% to 60% grade, and many rock facings and cliffs outcrop throughout the gorge.

The climate in the area is temperate and humid. Mean rainfall is 107 cm, and the average temperature is 1.7° C in the winter and 24° C in the summer. The climate is uniform throughout Jefferson County, although its effect is modified locally by runoff, direction of slope, steepness of slope, and proximity to the Ohio River (Nickell, 1985).

MATERIALS AND METHODS

The park naturalist, Richard Davis, identified some of the "most characteristic and least-disturbed" areas within the Preserve, and his observations provided the basis for selecting sampling sites for this study. Six sites were sampled: Hoffman Falls, both the south-facing (19 plots) and north-facing (15 plots) slopes; Tunnel Falls, both the west-facing (15 plots) and east-facing (12 plots) slopes; and two shallow tributary ravines, Little Clifty Creek (16 plots) and Big Clifty Creek (16 plots).

Trees, woody plants greater than 10 cm in diameter at breast height (dbh), were sampled in 0.04 ha circular plots. Plots were spaced at ca. 30 m intervals across the slopes and were positioned at lower, middle, and upper slope levels of the various aspects to insure an adequate sampling of the forest.

Tree data were analyzed to find density (trees/ha) and relative density (RD), basal area (m/ha) and relative dominance (RDo), importance value (IV), and species diversity (*H*). Species diversity was calculated using the Shannon-Wiener function:

$$H = -\sum_{i=1}^{s} (p_i)(\log_2 p_i)$$

where s is the number of species, and p_i is the proportion of the total sample belonging to the *i*th species (Shannon, 1948). The nomenclature follows Deam (1940).

The coefficient of determination (100r) was calculated using the correlation coefficient, r, relating stem counts to their size class based on dbh (Schmelz and Lindsey, 1965). A low coefficient of determination indicates a high level of disturbance. The similarity coefficient (C; Bray and Curtis, 1957) was used to compare the current sample with Braun's (1950). The equation for calculating similarity is:

$$C = (2W)/(a + b)$$

where a equals the sum of the RDs for our sample, b equals the sum of the RDs for Braun's sample, and w is the sum of the lower values for the species that occur in both samples. The equitability (evenness) of the stand (E) was calculated using a method based on the Shannon-Wiener function (H):

$$E = H/H_{max}$$

where H_{max} is the diversity under maximum equitability ($H = \log_2 S$), and S is the number of species in the sample.

RESULTS

The current sample totaled 30 tree species and 1154 individuals. The most important species (Table 1) were *Acer saccharum* (sugar maple, IV = 62.31), *Quercus rubra* (red oak, IV = 24.05), *Q. muehlenbergii* (chinquapin oak, IV = 16.66), *Fraxinus americana* (white ash, IV = 16.46), and *Tilia heterophylla* (white basswood, IV = 10.49). There were 306.5 trees/ha with a mean basal area of 26.12 m/ha. Tree species diversity (H) was 3.36. The forest has been protected from logging and other major disturbances for over 70 years, and this protection was reflected by a coefficient of determination of 94.84.

The similarity coefficient (C) between this total forest sample and Braun's (1950) was 51%. Since Braun (1950) only reported on canopy trees, the current sample was subdivided into canopy and subcanopy species using a minimum dbh of 30 cm as the criterion for being considered a canopy species (*sensu* Abrell and Jackson, 1977). The values of RD, RDo, IV, and H were recalculated for this subsample. Canopy trees accounted for only 37% of the individuals in the current sample but for more than 79% of the basal area. The similarity (C) between the current sample of canopy trees and Braun's (1950) was 61%.

Twenty-two tree species occurred in the canopy. Sugar maple accounted for 42.55% of the trees in the total forest, but only 16.95% in the canopy, where it ranked behind red oak in basal area (RDo) and IV (Table 2). In the subcanopy, sugar maple contributed ca. 57% of the individuals. The next most important species, chinquapin oak, made up ca. 5% of the trees in the subcanopy. Some species, *Cercis canadensis, Cornus florida, Ostrya virginiana,* and *Carpinus caroliniana,* are generally confined to the subcanopy.

Table 1. The number (N), relative density (RD), relative dominance (RDo), and importance value (IV) for all tree species greater than 10 cm dbh at Clifty Canyon Nature Preserve, Clifty Falls State Park, Indiana.

	N	RD	RDo	IV
Acer saccharum	491	42.55	19.76	62.31
Quercus rubra	86	7.45	16.60	24.05
Quercus muehlenbergii	79	6.85	9.81	16.66
Fraxinus americana	78	6.76	9.70	16.46
Tilia heterophylla	48	4.16	6.33	10.49
Liriodendron tulipifera	34	2.95	6.19	9.14
Fagus grandifolia	32	2.27	5.31	8.08
Quercus alba	28	2.43	5.18	7.61
Fraxinus quadrangulata	31	2.69	3.59	6.28
Juglans nigra	23	1.99	3.62	5.61
Carya cordiformis	34	2.95	2.63	5.58
Aesculus octandra	35	3.03	2.51	5.54
Ulmus rubra	31	2.69	1.33	4.02
Carya ovata	22	1.91	0.93	2.85
Celtis occidentalis	21	1.82	0.51	2.33
Sassafras albidum	14	1.21	0.79	2.00
Prunus serotina	9	0.78	1.13	1.91
Quercus velutina	8	0.69	1.05	1.74
Ostrya virginiana	16	1.39	0.21	1.60
Carya glabra	5	0.43	1.01	1.44
Platanus occidentalis	6	0.52	0.88	1.40
Cornus florida	7	0.61	0.09	0.70
Ulmus americana	4	0.35	0.16	0.51
Carpinus caroliniana	5	0.43	0.06	0.49
Quercus shumardii	1	0.09	0.33	0.42
Quercus coccinea	1	0.09	0.18	0.27
Cercis canadensis	2	0.17	0.03	0.20
Juniperus virginiana	1	0.09	0.05	0.14
Nyssa sylvatica	1	0.09	0.01	0.10
Aesculus glabra	1	0.09	0.01	0.10
Totals	1154	100.03	99.99	200.02

Eight species each contributed more than 5% to the canopy basal area and seven species more than 5% of the density (Table 2). Species diversity (H) was 3.72 in the canopy and 2.80 in the subcanopy. Red oak was the canopy dominant based on IV (Table 2), followed by sugar maple, white ash, chinquapin oak, tulip tree (*Liriodendron tulipifera*), white basswood, beech (*Fagus grandifolia*), and

Table 2. The number (N), relative density (RD), relative dominance (RDo), and importance value (IV) for all canopy tree species greater than 30 cm dbh at Clifty Canyon Nature Preserve, Clifty Falls State Park, Indiana.

	N	RD	RDo	IV
Quercus rubra	64	15.50	20.02	35.52
Acer saccharum	70	16.95	11.39	28.34
Fraxinus americana	46	11.14	10.56	21.70
Quercus muehlenbergii	41	9.93	11.01	20.94
Liriodendron tulipifera	30	7.26	7.72	14.98
Tilia heterophylla	29	7.02	7.41	14.43
Fagus grandifolia	23	5.57	6.42	11.99
Quercus alba	18	4.36	9.11	10.47
Juglans nigra	17	4.12	4.17	8.29
Fraxinus quadrangulata	15	3.63	3.24	6.87
Carya cordiformis	15	3.63	2.32	5.95
Aesculus octandra	10	2.42	2.28	4.70
Quercus velutina	7	1.69	1.32	3.01
Ulmus rubra	7	1.69	1.07	2.76
Prunus serotina	5	1.21	1.28	2.49
Platanus occidentalis	4	0.97	0.96	1.93
Carya glabra	3	0.73	1.16	1.89
Sassafras albidum	3	0.73	0.44	1.17
Carya ovata	3	0.73	0.40	1.13
Quercus shumardii	1	0.24	0.41	0.65
Quercus coccinea	1	0.24	0.23	0.47
Celtis occidentalis	1	0.24	0.09	0.33
Totals	413	100.00	100.01	200.01

white oak (*Quercus alba*). The RDs for six of the ten species common to Braun's (1950) sample and the current canopy sample showed significant differences (Table 3).

DISCUSSION

The current study supports Braun's (1950) contention that the Clifty Canyon Nature Preserve of the CFSP forest is a mixed mesophytic community. In southeastern Indiana, mixed mesophytic stands are characteristic of the steeper slopes, especially on cherty limestone soils (Lindsey, *et al.,* 1965) such as at CFSP. The indicator species for the Mixed Mesophytic Forest Region, *Tilia heterophylla* and *Aesculus octandra* (Braun, 1950), were prominent in Braun's and, to a lesser extent, in the current sample (Table 3). However, two differences

Table 3. A comparison of Braun's (1950) canopy percentages with the 1991 canopy percentages for Clifty Canyon Nature Preserve, Clifty Falls State Park, Indiana.

	Braun	1991
Fagus grandifolia	27.50	5.57*
Acer saccharum	20.00	16.95
Tilia heterophylla	15.00	7.02*
Liriodendron tulipifera	8.80	7.26
Quercus rubra	10.00	15.50*
Fraxinus americana	8.80	11.14
Aesculus octandra	6.30	2.42*
Juglans nigra	1.20	4.12*
Celtis occidentalis	1.20	0.24
Quercus muehlenbergii	1.20	9.93*

* Significant difference at the 0.01 level (*z*-test).

were noted between the two samples. First, the high diversity characteristic of all-deciduous mixed mesophytic forests (Monk, 1967; Martin, 1992) was found in both the total sample ($H = 3.36$) and the canopy ($H = 3.72$) in the current study but was considerably lower ($H = 2.47$) for Braun's (1950) sample. Second, 22 of the 30 tree species encountered in this study were recorded in the canopy, but Braun listed only 10 canopy members. The percent differences between the canopy composition of the two samples indicates that Braun's sample was too small (80 trees) to be representative of the broad species diversity as it relates to the underlying topographic diversity at CFSP.

Braun's sample (Table 3) was probably taken from only one area of CFSP, the upland bench and adjacent Little Clifty Creek near the main shelterhouse. This area is the only site known at CFSP having a concentration of canopy-size beech. The other nine species in Braun's table also occur in this area. Scott (1926) also noted that beech was an important species at CFSP. However, beech was of minor importance in the current study except in a few local areas. Some changes in forest structure and composition may occur over the time period between the two samplings but not to the extent found in this study. Bray and Curtis (1957) reported that replicate samples in the same forest typically should have similarity values of ca. 80% to 85%. The similarity values for the two samples at CFSP were 51% and 61% for the total forest and canopy, respectively.

The CFSP forest has been preserved for over 70 years and appears to have a high degree of stability as judged by the coefficient of determination (94.84). Basal area and density values for CFSP are also comparable to those reported for mature mixed mesophytic forests (Martin, 1992). At various sites, basal area exceeds the 30 m/ha suggested for climax mesic forests in the Midwest (Held and Winstead, 1975). Tornados that hit Jefferson County during 1974 (Bailey and MacMillan, 1977; Martin and MacMillan, 1982) did not touch down in Clifty Canyon. Disturbances there are the result of occasional blowdowns, uprootings, and trail work.

Species diversity for both the total forest and the canopy are greater than 3.0, which is characteristic of mixed mesophytic forests (Martin, 1992). The evennness for the entire forest was 0.68 and for the canopy, 0.83. Both values show the contributions of the many species in mixed mesophytic forests (Braun, 1950; Martin, 1992).

Lindsey, *et al.* (1965) found that the pre-settlement forests of southeastern Indiana were dominated by trees in four genera — *Fagus, Quercus, Acer,* and *Carya.* The species in those four genera contributed ca. 60% to both the density and basal area at CFSP (Table 2). By including *Fraxinus,* the contributions were ca. 75% in each. However, the RD and RDo contributions for *Tilia* and *Liriodendron* were greater than for either *Fagus* or *Carya,* suggesting an overemphasis of beech by Braun (1950) and an underestimation of the other species.

Red oak is the leading canopy member in the current sample. Another oak species, chinquapin, is generally a minor associate in the mixed mesophytic complex except in those areas marked by outcrops of Ordovician and Silurian limestone such as are found in CFSP (Reynolds and Potzger, 1950). Chestnut oak (*Quercus prinus*), a disjunct species at CFSP (Deam, 1940), is confined to one or two small areas in the park and did not fall within our sampling plots.

By combining all aspects and slope positions, some of the variation between sites at CFSP was obscured. However, the combined data give a more realistic view of the CFSP forest than has been presented previously.

ACKNOWLEDGMENTS

The authors extend their appreciation to the Indiana Department of Natural Resources and the Division of State Parks for granting permission for this study at Clifty Falls State Park. Special thanks go to Richard Davis, Park Naturalist at CFSP, for his help during field research for this paper.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 139-184

THE FLORA AND VEGETATION OF RAVEN RUN NATURE SANCTUARY, FAYETTE COUNTY, KENTUCKY

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ABSTRACT: The vascular flora of Raven Run Nature Sanctuary, Fayette County, Kentucky, is described, and the significance of this natural area in the Inner Bluegrass Region is discussed. A total of 541 vascular plant species have been documented, including 112 non-native species and 23 rare native species. The forest is divisible into four intergrading types largely defined by dominant species: 1) *Juniperus* on dry or eroded, successional sites; 2) *Juglans-Celtis-Fraxinus* or *Robinia-Prunus* on moist, successional sites; 3) *Quercus-Fraxinus* on relatively dry, undisturbed sites; and 4) *Acer saccharum* or *A. nigrum* on relatively moist, undisturbed sites. Old fields on the broader ridges with deeper soil are divisible into (1) recently plowed or disked areas with weedy species, (2) former pastures or grassy mowed areas, and (3) brushy disturbed areas. Species in the Sanctuary which are rare in Kentucky include *Allium burdickii, Malvastrum hispidum, Onosmodium hispidissimum, Prenanthes crepidinea, Prunus virginiana, Solidago harrisii,* and *Viburnum molle.* Rare species in the Bluegrass Region that are more frequent elsewhere in the State include *Aplectrum hyemale, Aureolaria flava, Carex laxiculmis, C. plantaginea, Chimaphila maculata, Goodyera pubescens, Monotropa uniflora, Pachysandra procumbens, Panicum anceps,* and *Tipularia discolor.* Most rare species are present in the less disturbed forest of more rugged areas, except for *M. hispidum* and *O. hispidissimum,* which occur in rocky, old fields. Non-native species are mostly confined to old fields. A few exotic shrubs and vines, *Lonicera maackii, L. japonica, Hedera helix,* and *Euonymus fortunei,* occur mostly in the woods.

KEYWORDS: Fayette County, Kentucky records — vascular plants, flora, forest types, introduced species, old field succession, rare species, Raven Run Nature Sanctuary — flora.

INTRODUCTION

The Palisades section of the Kentucky River Valley is centered between Camp Nelson and High Bridge with an outlying eastern area centered near Clays Ferry. The vascular flora of this area is relatively diverse compared to other sections of the Bluegrass Region. This diversity was described as a whole by Martin, *et al.* (1979), but only two intensive surveys of specific sites (Panther

Rock near the downstream end of the Palisades (Bryant, 1973) and Jessamine Creek Gorge in the central Palisades (Campbell and Meijer, 1989)) have been carried out. The botanical features of a third area, Raven Run, within the outlying eastern part of the Palisades is the focus of this study.

Raven Run Nature Sanctuary, a 375 acre tract located in southeastern Fayette County (Figure 1), is owned by the Lexington-Fayette Urban-County Government and is managed for biological conservation and passive recreation by the Division of Parks and Recreation. One hundred of these acres were incorporated into the Sanctuary following the completion of this study and are not detailed in this report. The Sanctuary was established during 1977-1982 and is registered as a Natural Area by the Kentucky State Nature Preserves Commission.

This study was initiated at the request of the Raven Run Advisory Board in order to update the flora and describe the distribution of plant communities in the Sanctuary for educational programs and management considerations. The objectives were to: 1) identify areas with rare species; 2) update existing lists of the vascular flora; 3) produce a vegetation map of the Sanctuary; 4) advise on management plans and on the potential impacts involving mowing regimes in the fields, promotion of attractive wild flowers, release of some fields from mowing, forest succession on ridgetops, location of trails, and possible effects of a Kentucky River impoundment. Details of the management applications are excluded here but were part of the report to the Department of Parks and Recreation (Campbell and Ruch, 1990). In addition to botanical description, the regional significance of the Raven Run area as a site for the long-term study of succession and the spread of exotic species is addressed in this paper.

THE STUDY AREA

The Raven Run Sanctuary lies in the Inner Bluegrass Region of north-central Kentucky, which is underlain by Middle Ordovician bedrock (450-480 million years old). Most bedrock on the uplands is the Lexington Limestone, containing phosphatic beds that have weathered to produce some highly fertile soils. Deeper ravines along the Kentucky River, including Raven Run, expose the older High Bridge Group of rocks, mostly non-phosphatic limestones and dolomites. The Upper Ordovician Eden Shale is virtually absent at Raven Run, although some of the soils on ridges may have a minor residual component derived from this rock unit, and a few vegetational features may be related to it. For example, the northern area, which is underlain by the Salvisa soil series (Sims, *et al.,* 1968), has the only *Sassafras* in the Sanctuary.

Within the Inner Bluegrass, two major types of topography are found: the largely agricultural, gentler slopes, including the Lexington Plain; and the narrow, forested zone on steeper slopes near the Kentucky River, including the Palisades. A gradual transition occurs in soils between these two topographic regions (Sims, *et al.,* 1968) from the deeper Maury soil series on gentler (2-6%) slopes, to the McAfee soil series on intermediate (6-12%) slopes, to the shallower Fairmount soil series on steeper (12-30%) slopes. Steep and intermediate slopes are predominant at Raven Run. The Sanctuary is bounded by Chandler Creek and the forks of Raven Run Creek. The seasonal Collinsia Creek (formerly known as Rabbit Town Branch) runs through the center of the Sanctuary.

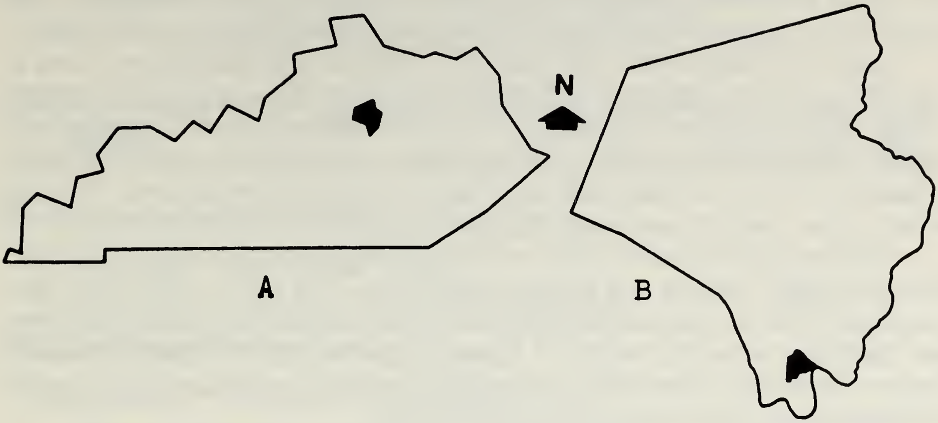

Figure 1. **A.** Map of Kentucky showing the location of Fayette County (darkened). **B.** Fayette County enlarged showing the location of the Raven Run Nature Sanctuary (darkened).

The Sanctuary has been greatly disturbed in the past and is now recovering. The Raven Run Sanctuary contains areas of mixed hardwood forest, successional red cedar forest, old fields, and mowed fields. After 1810-1830, three farms existed in the area (Prather near Jack's Creek Pike; Moore in the center; and Brink in the northern section). Several homes (including Rabbit Town), a mill (Evan's Mill), and a lime kiln were formerly located here. Mature forest, with a composition similar to the presettlement state (Campbell 1980, 1989), is mostly confined to steeper slopes near the Kentucky River. The fields remaining today on the broader ridges were farmed until the 1960s. At that time, the City of Lexington acquired the area and used part as a land-fill for several years.

MATERIALS AND METHODS

Over the past fifty years, the plants of Raven Run have been studied by several botanists, including Mary Wharton, Edward Browne, and Willem Meijer. These investigators began compiling lists and documenting the vascular flora of the area. Additionally, members of the Thursday Morning Hiking Group (TMHG), an amateur botanical group, have surveyed Raven Run nearly every week for the past 15 years, recording many important botanical observations.

During the 1989 growing season, biweekly forays were made in the Sanctuary and on adjacent slopes to verify previous floral records and to add new ones. This effort was continued on a less intensive basis during the 1990 and 1991 seasons. Simultaneously, collections stored at the University of Kentucky herbarium were re-examined. Vegetation in each section of the Sanctuary was described and related to shifts in topography and relative abundance of species (Figure 2). Aerial photographs were helpful in determining these delineations. Additionally, the soil survey of Fayette County (Sims, *et al.*, 1968) was used to help interpret the vegetation patterns. Notes on vegetation consisted of species lists, with visual estimates of their abundance (see catalog of vascular plants below). Lists were sorted into vegetation types based on common dominant species and species composition. A special effort was made to document populations and environments of the rarer species and some exotic species. More detailed maps are available from the senior author.

Quantitative data from 17 circular plots were gathered from forested areas in 1977-78 and are presented here to illustrate the variation in tree species composition. These plots were placed systematically in different forest types. Trees having a diameter equal to or greater than 10 cm at breast height (dbh) were recorded within a radius of 15 m, and these data were used to determine basal areas. Smaller woody stems and herbaceous species were listed within a radius of 10 m.

Gleason and Cronquist (1991) was used as the primary taxonomic reference. Fernald (1950), Kartesz and Kartesz (1980), and Voss (1972, 1985) were also consulted for a few taxa and other details of identification. Herbarium specimens are deposited in the University of Kentucky herbarium. In 1989, the authors observed over 95% of the listed species at Raven Run or on adjacent slopes (north of Raven Run Creek, south of Chandler Branch).

RESULTS

The following catalog of the vascular plants found in the Raven Run Nature Sanctuary is arranged alphabeticllay by family. The ecological codes on the right margin are as follows:

> **Flowering or sporulating date (Flw):** 3-10 = months March to October (along this sequence, peak months for white/cream flowered herbaceous species are distributed 10/25/13/8/6/8/6/0; yellowish/greenish ones are 0/14/5/2/22/12/5/0; blue ones are 0/10/7/4/4/2/2/2; purple/pink/red ones are 1/4/7/6/9/11/1/1; wind pollinated ones are 1/7/30/13/18/16/0/0; and woody species (mostly white/greenish or wind-pollinated) are 5/26/36/14/4/3/0/0).
>
> **Typical habitat (Hab):** A-G = vegetation types as listed in the text; in addition, GA = streams or other wet spots in or near fields; X = largely restricted to rock outcrops; and Y = under rock overhangs.
>
> **Relative abundance (Rel):** r = rare (< 10 sites); o = occasional, not widespread throughout the Sanctuary, even in suitable habitat; c = common (or frequent) throughout the Sanctuary, typically not in great numbers (although occasionally a species may be locally abundant); and d = abundant throughout the Sanctuary, often locally abundant in suitable habitat.

Superscripts (1 to 4) refer to the following notes: 1 = collected by Robert Peter in 1834 from the bank of the Kentucky River at or near "Raven Creek" (MacFarlane, 1979); 2 = found on the point north of the mouth of Raven Run Creek; 3 = found on other slopes north of the Sanctuary; and 4 = found on other slopes just outside the Sanctuary (see text). The "§" in the left column indicates naturalized, non-native plant species. The "?" in the left column indicates that the record is uncertain. These species were reported from the Sanctuary by other botanists, but no adequate voucher specimens were taken. Common synonyms are in parentheses.

CATALOG OF THE VASCULAR PLANTS OF THE RAVEN RUN NATURE SANCTUARY ARRANGED ALPHABETICALLY BY FAMILY

Species	Flw	Hab	Rel
DIVISION EQUISETOPHYTA (Scouring Rushes)			
Equisetaceae — Horsetail Family			
Equisetum hyemale L.; Common scouring rush		GA	r
DIVISION POLYPODIOPHYTA (Ferns)			
Adiantaceae — Maidenhair Fern Family			
Adiantum pedatum L.; Northern maidenhair fern	6-8	F	o
Aspleniaceae — Spleenwort Family			
Asplenium platyneuron (L.) Oakes; Ebony spleenwort	4-10	C	d
Asplenium rhizophyllum L.; Walking fern	5-9	FX	o
Athyrium pycnocarpon (Spreng.) Tidestrom; Glade fern	7-9	F	o
Cystopteris bulbifera (L.) Bernh.; Bulblet bladder fern	6-9	FX	d
Cystopteris protrusa (Weatherby) Blasdell; Lowland bladder fern	6-9	F	d
Dryopteris marginalis (L.) Gray; Marginal woodfern	6-9	F	c
Polystichum acrostichoides (Michx.) Schott; Christmas fern	6-10	C	r
Woodsia obtusa (Spreng.) Torr.; Blunt cliff-fern	5-10	EX	o
Ophioglossaceae — Adder's Tongue Family			
Botrychium dissectum Spreng. var. *obliquum* (Muhl.) Clute; Lace-frond grape fern	9-10	C	o
Botrychium virginianum (L.) Swartz; Rattlesnake fern	5	D	o
Ophioglossum vulgatum L. var. *pycnostichum* Fern; Southern adder's tongue	5	C	r
DIVISION PINOPHYTA (Gymnosperms)			
Cupressaceae — Cypress Family			
Juniperus virginiana L.; Eastern red cedar		C	d
Pinaceae — Pine Family			
§ *Pinus strobus* L.; White pine	5	E	r

Species	Flw	Hab	Rel
DIVISION MAGNOLIOPHYTA (Flowering Plants)			
DICOTYLEDONAE (Dicotyledons)			
Acanthaceae — Acanthus Family			
Justicia americana (L.) Vahl; American water-willow	7-8	GF	o-d
Ruellia strepens L.; Rustling ruellia	6-7	A	o
Aceraceae — Maple Family			
Acer negundo L.; Boxelder	4	G	d
Acer nigrum Michx. f.; Black maple	5-6	F	d
Acer saccharinum L.; Silver maple	2-4	GR	o
Acer saccharum Marsh.; Sugar maple	4-5	F	d
Anacardiaceae — Cashew Family			
Rhus aromatica Ait.; Squaw-bush or fragrant sumac	4	E	c
? *Rhus copallina* L.; Shining sumac	7	A	r
Rhus glabra L.; Smooth sumac	6-7	A	d
Toxicodendron radicans (L.) Kuntze; Common poison-ivy	6	C	d
Annonaceae — Custard-Apple Family			
Asimina triloba (L.) Dunal; Pawpaw	4	F	c
Apiaceae — Carrot Family			
Chaerophyllum procumbens (L.) Crantz; Spreading chervil	4-5	D	d
Chaerophyllum tainturieri Hook.; Southern chervil	4-5	A	o
§ *Conium maculatum* L.; Poison hemlock	6-7	A	o
Cryptotaenia canadensis (L.) DC.; Honewort	6-8	GD	c
§ *Daucus carota* L.; Wild carrot or Queen Anne's lace	7-8	A	c
Erigenia bulbosa (Michx.) Nutt.; Harbinger of spring	2-4	F	o
Osmorhiza claytonii (Michx.) Clarke; Bland sweet cicely	5	F	c
Osmorhiza longistylis (Torr.) DC.; Long-styled sweet cicely	5	D	c
§ *Pastinaca sativa* L.; Parsnip	6	A	o
Sanicula canadensis L.; Canada sanicle	5-6	D	o
Sanicula gregaria Bickn.; Cluster sanicle	4-6	C	o
Sanicula trifoliata Bickn.; Beaked sanicle	6	F	o

	Species	Flw	Hab	Rel
	Taenidia integerrima (L.) Drude; Yellow pimpernel	5	E	o
	Thaspium barbinode (Michx.) Nutt.; Bearded meadow-parsnip	5-6	F	c
	Thaspium trifoliatum (L.) Gray var. *flavum* Blake; Smooth meadow-parsnip	4-5	F	r
§	*Torilis arvensis* (Hudson) Link. (*T. japonica*); Field hedge-parsley	7	C	o
	Zizia aptera (Gray) Fern.; Heart-leaved golden alexanders	5	E	o
Apocynaceae — Dogbane Family				
	Apocynum cannabinum L.; Hemp-dogbane	6-7	A	c
Aquifoliaceae — Holly Family				
§	*Ilex opaca* Ait.; American holly	5	C	r
Araliaceae — Ginseng Family				
§	*Hedera helix* L.; English ivy	9-3?	F	d
	Panax quinquefolium L.; American ginseng	6-7	F[4]	r
Aristolochiaceae — Birthwort Family				
	Aristolochia serpentaria L.; Virginia snakeroot	5-7	E	o
	Asarum canadense L.; Wild ginger	4	F	d
Asclepiadaceae — Milkweed Family				
	Asclepias quadrifolia Jacq.; Four-leaved milkweed	5-6	E	o
	Asclepias syriaca L.; Common milkweed	6-7	A	c
	Ampelamus albidus (Nutt.) Britt. (*Cynanchum laeve*); Sandvine	7-9	A	o
Asteraceae — Aster Family				
§	*Achillea millefolium* L.; Common yarrow	6-7	A	c
	Ambrosia artemisiifolia L. var. *elatior* (L.) Descourt; Common ragweed	7-9	A	c
	Ambrosia trifida L.; Giant ragweed	7-8	G	o
	Antennaria plantaginifolia (L.) Richardson; Plantain pussytoes	4-5	E	r
§	*Arctium minus* Schk.; Common burdock	7-9	A	o
§	*Artemisia annua* L.; Annual wormwood	8-9	A	o
	Aster cordifolius L.; Common blue heart-leaved aster	10	F	c
?	*Aster lanceolatus* Willd. var. *simplex* (Willd.) Jones; Eastern lined aster	9-10	G	o

Species	Flw	Hab	Rel
Aster lateriflorus (L.) Britt.; Goblet aster	9-10	C	o
Aster novae-angliae L.; New England aster	10	A	o
Aster oblongifolius Nutt.; Aromatic aster	10	E	o
Aster ontarionis Wieg.; Bottomland aster	9-10	G	d
Aster pilosus Willd.; Awl aster	9-10	A	d
Aster shortii Lindley; Midwestern blue heart-leaved aster	9-10	E	d
Bidens aristosa (Michx.) Britt.; Midwestern tickseed-sunflower	9-10	G	o
Bidens bipinnata L.; Spanish needles	8-10	A	o
Bidens frondosa L.; Devil's beggar-ticks	8-10	G	o
§ *Carduus nutans* L.; Musk thistle	6-8	A	o
§ *Chrysanthemum leucanthemum* L. (*Leucanthemum vulgare* L. var. *pinnatifidum*); Ox-eye daisy	6-7	A	c
§ *Cichorium intybus* L.; Chickory	6-9	C	o
Cirsium discolor (Muhl.) Spreng.; Field thistle	8-9	A	c
§ *Crepis pulchra* L.; Hawk's beard	2-6?	A	o
Eclipta prostrata L. (*E. alba*); Yerba-de-tajo	8-9	G	r
Erigeron annuus (L.) Pers.; Annual fleabane	6-7	D	d
Erigeron canadensis L. *(Conyza canadensis)*; Horseweed	7-10	A	d
Erigeron philadelphicus L.; Philadelphia daisy	5	D	c
Eupatorium coelestinum L.; Mistflower	8-10	G	o
Eupatorium incarnatum Walter; Pink eupatorium	9	C	r
Eupatorium perfoliatum L.; Boneset	8	G	o
Eupatorium purpureum L.; Purple-node joe-pye-weed	7-9	F	o
Eupatorium rugosum Houtt.; White snakeroot	8-9	D	c
Gnaphalium obtusifolium L.; Fragrant cudweed	9-10	A	o
Helianthus decapetalus L.; Forest sunflower	7-8	F	r
Helianthus microcephalus T. & G.; Small-headed sunflower	8-9	E[2]	r
Heliopsis helianthoides (L.) Sweet var. *scabra* (Dunal) Fern.; Sunflower everlasting	7-8	A	r
§ *Hypochoeris radicata* L.; Spotted cat's ear	6-7	A	r
Kuhnia eupatorioides L. (*Brickellia eupatorioides*); False boneset	8-9	A	o

	Species	Flw	Hab	Rel
	Lactuca canadensis L.; Tall lettuce	7-9	A	o
	Lactuca floridana (L.) Gaertn.; Woodland lettuce	8-9	C	o
§	*Lactuca serriola* L.; Prickly lettuce	7-9	A	o
§	*Matricaria matricarioides* (Lessing) Porter; Pineapple-weed	6-9	A	o
	Polymnia canadensis L.; Pale-flowered leafcup	7-9	F	d
	Polymnia uvedalia L.; Yellow-flowered leafcup	7-8	D	o
	Prenanthes altissima L.; Tall white lettuce	8-9	F	o
	Prenanthes crepidinea Michx.; Midwestern white lettuce	8-10	FD	r
	Rudbeckia fulgida Ait.; Eastern coneflower	8-9	A	o
	Rudbeckia hirta L. var. *pulcherrima* Farw. (*R. serotina*); Black-eyed Susan	7-8	A	c
	Rudbeckia triloba L.; Three-lobed coneflower	7-8	A	d
	Senecio aureus L.; Heart-leaved groundsel	4-5	GF	o
	Senecio obovatus Muhl.; Running groundsel	4	CE	c
	Solidago altissima L. (*S. canadensis* L. var. *scabra*); Common goldenrod	9	A	d
	Solidago caesia L.; Axillary goldenrod	9-10	E	d
	Solidago flexicaulis L.; Zigzag goldenrod	9	F	d
?	*Solidago gigantea* Ait.; Smooth goldenrod	8-9	A	o
	Solidago harrisii Steele: Forest goldenrod	8-9	E^2	r
	Solidago rupestris Raf.; Riverbank goldenrod	8-9	B	o
	Solidago sphacelata Raf.; Short-pappus goldenrod	9	E	c
	Solidago ulmifolia Muhl.; Elm-leaved goldenrod	8-9	E	d
§	*Taraxacum officinale* Weber; Common dandelion	2-10	A	o
§	*Tragopogon dubius* Scop. (*T. major*); Fistulous goat's beard	5-7	A	o
	Verbesina alternifolia (L.) Britt (*Actinomeris alternifolia*); Wingstem	8-9	G	o
	Verbesina occidentalis (L.) Walt.; Southern flatseed sunflower	8-10	A	d
	Vernonia gigantea (Walt.) Trel. (*V. altissima*); Tall ironweed	8-9	A	d
§	*Xanthium strumarium* L.; Common cocklebur	7-9	A	r

Species	Flw	Hab	Rel
Balsaminaceae — Touch-Me-Not Family			
Impatiens capensis Meerb.; Orange touch-me-not	7-8	G	d
Impatiens pallida Nutt.; Yellow touch-me-not	7-8	FG	d
Berberidaceae — Barberry Family			
Caulophyllum thalictroides (L.) Michx.; Blue cohosh	4	F	o
Jeffersonia diphylla (L.) Pers.; Twinleaf	3-4	E	d
Podophyllum peltatum L.; Mayapple or mandrake	4-5	F	d
Betulaceae — Birch Family			
Carpinus caroliniana Walt.; Hornbeam or blue beech	4-5	F	c
Ostrya virginiana (Miller) Koch; Hop-hornbeam	4-5	E	d
Bignoniaceae — Trumpet-Creeper Family			
Bignonia capreolata L. (*Anisostichus capreolata*); Crossvine	5	F	c
Campsis radicans (L.) Seemann; Trumpet-creeper	7	A	c
Boraginaceae — Borage Family			
§ *Echium vulgare* L.; Blue-weed	6-8	AX	o
§ *Lithospermum arvense* L.; Corn gromwell	4-5	A	o
Mertensia virginica (L.) Pers.; Eastern bluebell	4	F	o
Myosotis macrosperma Engelm.; Big-seed scorpion-grass	4-5	D	r
Onosmodium hispidissimum Mack. (*O. molle* var. *hispidissimum*); Western false gromwell	6-7	A	r
Brassicaceae — Mustard Family			
§ *Alliaria petiolata* (Bieb.) Cavara & Grande; Garlic mustard	5	D	r
Arabis laevigata (Muhl.) Poiret; Rock-cress	4-5	E	c
§ *Barbarea vulgaris* R. Brown; Yellow rocket	4-5	A	c
§ *Capsella bursa-pastoris* (L.) Medikus; Shepherd's purse	3-11	A	o
Cardamine douglassii Britt.; Pink springcress	3-4	F	c
§ *Cardamine hirsuta* L.; Hoary bittercress	2-4	A	c
? *Cardamine pensylvanica* Muhl.; Pennsylvania bittercress	3-7	G	o
Dentaria diphylla (Michx.) Wood (*Cardamine diphylla*); Broad-leaved toothwort	4	F	c
Dentaria laciniata Muhl. (*Cardamine concatenata*); Five-parted toothwort	3-4	F	c

	Species	Flw	Hab	Rel
	Draba ramosissima Desv.; Branched rock-cress	4-5	E	r
	Draba verna L.; Whitlow-grass	2-4	A	c
§	*Erysimum repandum* L.; Treacle mustard or bushy wallflower	5-6	A	r
	Iodanthus pinnatifidus (Michx.) Steud.; Purple rocket	5	G	r
§	*Lepidium campestre* (L.) R. Brown; Field cress	4-8	A	c
	Lepidium virginicum L.; Poor-man's pepper	5-6	A	c
§	*Rorippa nasturtium-aquaticum* (L.) Hayek. (*Nasturtium officinale*); Water-cress	5-7	GA	o
	Sibara virginica (L.) Rollins; Little field cress	3-5	A	r
§	*Thlaspi perfoliatum* L.; Thoroughwort pennycress	3	A	o
Buxaceae — Boxwood Family				
	Pachysandra procumbens Michx.; Allegheny spurge	4	F	o
Caesalpiniaceae — Caesalpinia Family				
	Cercis canadensis L.; Redbud	4	C	c
	Gleditsia triacanthos L.; Honeylocust	5-6	C	c
	Gymnocladus dioicus (L.) Koch; Kentucky coffeetree	5-6	D	o
	Senna marilandica (L.) Link (*Cassia marilandica*); Southern wild senna	7-8	A	o
Campanulaceae — Bellflower Family				
	Campanula americana L.; Tall bellflower	6-8	CD	c
	Lobelia inflata L.; Indian tobacco	7-8	A	c
	Lobelia siphilitica L.; Great lobelia	8-9	G	o
	Triodanis perfoliata (L.) Nieuwl. (*Specularia perfoliata*); Round-leaved triodanis	5-6	A	c
Caprifoliaceae — Honeysuckle Family				
	Lonicera dioica L.; Wild honeysuckle	5	FX	o
§	*Lonicera japonica* Thunb.; Japanese honeysuckle	5-7	AC	d
§	*Lonicera maackii* (Rupr.) Maxim; Manchurian bush honeysuckle	5-6?	CD	d
	Sambucus canadensis L.; Common elderberry	6	G	o
	Symphoricarpos orbiculatus Moench; Coralberry	7-8	A	d
	Triosteum aurantiacum Bickn.; Perfoliate horsegentian	5	E	o
	Viburnum molle Michx.; Missouri arrow-wood	6-7	F	r
	Viburnum prunifolium L.; Black haw	4	D	o

Species	Flw	Hab	Rel
Viburnum rafinesquianum Schultes var. *affine* (Bush) House; Downy arrow-wood	5	E	o
Viburnum rufidulum Raf.; Southern black haw	5	C	c
Caryophyllaceae — Pink Family			
Arenaria patula Michx. var. *robusta* (Steyerm.) Maguire; Limestone stitchwort	4-5	EX	c
§ *Arenaria serpyllifolia* L.; Thymeleaf sandwort	5-7	A	r
§ *Cerastium fontanum* ssp. *triviale* Baumg. (*C. vulgatum*); Mouse-ear chickweed	3-10	A	o
§ *Cerastium glomeratum* Thuillier (*C. viscosum*); Clammy chickweed	3-7	A	c
§ *Dianthus armeria* L.; Deptford-pink	6-7	A	c
§ *Holosteum umbellatum* L.; Jagged chickweed	3-5	A	o
§ *Saponaria officinalis* L.; Soapwort	6-9	A	c
Silene caroliniana Walt. var. *wherryi* (Small) Fern.; Wild pink	5	E	o
Silene rotundifolia Nutt.; Round-leafed fire-pink	5-7	EY	r
Silene stellata (L.) Ait. f.; Starry campion	7	C	o
Silene virginica L.; Fire-pink	4-6	E	o
Stellaria corei Shinners (*S. pubera* var. *silvatica*); Star chickweed	4	F	d
§ *Stellaria graminea* L.; Common stitchwort	5-9	A	o
§ *Stellaria media* (L.) Villars; Common chickweed	3-10	D	d
Stellaria pubera Michx.; Star chickweed	4	E	o
Celastraceae — Staff-Tree Family			
Celastrus scandens L.; American bittersweet	5-6	C	o
§ *Euonymus alatus* (Thunb.) Siebold; Winged burning bush	5-6	C	r
Euonymus americanus L.; Strawberry-bush	5	F	r
Euonymus atropurpureus Jacq.; Wahoo	5-6	D	o
§ *Euonymus fortunei* (Turzc.) Hand.-Mazz.; Japanese running strawberry-bush	5-6	D	o-d
Euonymus obovatus Nutt.; Running strawberry-bush	5	E	o
Chenopodiaceae — Goosefoot Family			
§ *Chenopodium album* L.; Lamb's quarters	7-9	A	o

Species	Flw	Hab	Rel
Chenopodium standleyanum Aellen; Woodland goosefoot	7-9	EY[3]	r
Clusiaceae — Mangosteen Family			
§ *Hypericum perforatum* L.; Common St. John's-wort	7-8	A	o
Hypericum punctatum Lam.; Spotted St. John's-wort	7-8	C	o
Convolvulaceae — Morning-Glory Family			
§ *Convolvulus sepium* (L.) R. Brown (*Calystegia sepium*); Hedge-bindweed	5-8	A	r
Ipomoea pandurata (L.) Meyer; Wild potato	7-8	A	o
Cornaceae — Dogwood Family			
Cornus alternifolia L. f.; Pagoda dogwood	5	F	r
Cornus drummondii Meyer; Rough-leaved dogwood	6	A	o
Cornus florida L.; Flowering dogwood	4	E	r
Crassulaceae — Stonecrop Family			
Sedum pulchellum Michx.; Pink stonecrop	6	AX	o
§ *Sedum sarmentosum* Bunge; Yellow stonecrop	6	AX	r
Sedum ternatum Michx.; White stonecrop	4-5	FX	c
Cucurbitaceae — Gourd Family			
Sicyos angulatus L.; Bur cucumber	7-8	G	o
Dipsacaceae — Teasel Family			
§ *Dipsacus fullonum* L.; Common teasel	7-9	A	o
§ *Dipsacus laciniatus* L.; Cut-leaf teasel	7-9	A	r
Euphorbiaceae — Spurge Family			
Croton capitatus Michx.; Wooly croton	7-8	A	r
Croton monanthogynus Michx.; Prairie tea or one-seed croton	7-8	AX	c
Euphorbia commutata Engelm.; Tinted spurge	4-5	E	o
Euphorbia nutans Lag.; Eyebane	7-8	A	o
Fabaceae — Pea Family			
Amphicarpaea bracteata (L.) Fern.; Hog peanut	8	CG	o
Desmodium glutinosum (Muhl.) Wood; Cluster-leaf tick-trefoil	7-8	A	o
Desmodium perplexum Schubert; Common tick-trefoil	8-9	A	c
§ *Lathyrus latifolius* L.; Everlasting pea	6-8	A	r

Species	Flw	Hab	Rel
§ *Lathyrus sylvestris* L.; Narrow-leaved everlasting pea	6-7	A	r
§ *Lespedeza stipulacea* Maxim.; Korean clover	8-9	A	o
Lespedeza violacea (L.) Pers.; Violet lespedeza	7-8	E	o
§ *Medicago lupulina* L.; Black medick	4-10	A	o
§ *Medicago sativa* L.; Alfalfa	5-8	A	o
§ *Melilotus alba* Medikus; White sweet clover	5-8	A	o
§ *Melilotus officinalis* (L.) Pallas; Yellow sweet clover	5-8	A	o
Robinia pseudoacacia L.; Black locust	5	C	d
§ *Trifolium campestre* Schreber; Pinnate hop clover	5-8	A	d
§ *Trifolium hybridum* L.; Alsike clover	6-8	A	r
§ *Trifolium pratense* L.; Red clover	5-8	A	o
§ *Trifolium repens* L.; White clover	5-8	A	o
Vicia caroliniana Walt.; Pale vetch	4	F	r
§ *Vicia villosa* Roth ssp. *varia* (Host) Corb. (*V. dasycarpa*); Woolly-pod vetch	6	A	c
Fagaceae — Beech Family			
Fagus grandifolia Ehrh.; American beech	4	F	r
Quercus alba L.; White oak	5	E[3]	r
Quercus imbricaria Michx.; Shingle or jack oak	5	E	r
Quercus macrocarpa Michx.; Bur oak	5	AD[4]	r
Quercus muehlenbergii Engelm.; Yellow oak	5	E	d
Quercus rubra L. var. *borealis* (Michx. f.) Farw.; Northern red oak	5	F	c
Quercus shumardii Buckley; Shumard oak	5	E	d
Fumariaceae — Fumitory Family			
Corydalis flavula (Raf.) DC.; Short-spurred corydalis	4	D	o
Dicentra canadensis (Goldie) Walp.; Squirrel corn	4	FG	c
Dicentra cucullaria (L.) Bernh.; Dutchman's breeches	4	F	c
Gentianaceae — Gentian Family			
Frasera caroliniensis Walter (*Swertia caroliniensis*); American columbo	6	E[2]	o
Geraniaceae — Geranium Family			
Geranium carolinianum L.; Carolina crane's bill	5-7	A	o
Geranium maculatum L.; Wild geranium	4-5	F	o

Species	Flw	Hab	Rel
Grossulariaceae — Gooseberry Family			
Ribes cynosbati L.; Dogberry	4-5	FEX	o
Ribes missouriense Nutt.; Missouri gooseberry	5-6	E	r
Hamamelidaceae — Witch-Hazel Family			
? *Hamamelis virginiana* L.; Witch-hazel	10-11	F	r?
Hippocastanaceae — Horse-Chestnut Family			
Aesculus flava Ait. (*A. octandra*); Sweet or yellow buckeye	4-5	F	c
Aesculus glabra Willd.; Ohio buckeye	4	D	c
Hydrangeaceae — Hydrangea Family			
Hydrangea arborescens L.; American hydrangea	6	FG	d
Hydrophyllaceae — Waterleaf Family			
Hydrophyllum appendiculatum Michx.; Biennial waterleaf	5	G	c
Hydrophyllum canadense L.; Maple-leafed waterleaf	6	F	o
Hydrophyllum macrophyllum Nutt.; Hairy waterleaf	5-6	F	d
Phacelia bipinnatifida Michx.; Forest phacelia	4-5	FX	c
Phacelia purshii Buckley; Miami mist	4-5	D	d
Juglandaceae — Walnut Family			
Carya cordiformis (Wang.) Koch; Bitternut hickory	4-5	DF	d
Carya glabra (Miller) Sweet; Pignut hickory	5	E	r
Carya laciniosa (Michx. f.) Loudon; Shellbark hickory	4-5	DG	c
Carya ovata (Miller) Koch; Shagbark hickory	5	E	o
Juglans cinerea L.; Butternut	4-5	DC	r
Juglans nigra L.; Black walnut	4-5	D	d
Lamiaceae — Mint Family			
Agastache nepetoides (L.) Kuntze; Catnip giant hyssop	8	AC	o
§ *Ajuga reptans* L.; Carpet bugle	5-6	D	r
Blephilia ciliata (L.) Benth.; Downy wood-mint	6	CE	c
Collinsonia canadensis L.; Northern horse-balm	8	F	o
§ *Glecoma hederacea* L.; Gill-over-the-ground	4-5	D	c
§ *Lamium amplexicaule* L.; Henbit	3-4	A	o

Species	Flw	Hab	Rel
§ *Lamium purpureum* L.; Red dead nettle	3	D	d
§ *Leonurus cardiaca* L.; Motherwort	6-7	A	o
§ *Mentha spicata* L.; Spearmint	7-8	GA	o
Monarda fistulosa L. var. *mollis* (L.) Benth.; Wild bergamot	7-8	A	c
Prunella vulgaris L. var. *lanceolata* (Barton) Fern.; Selfheal	7-8	D	o
Salvia lyrata L.; Lyre-leaved sage	5	A	o
Scutellaria elliptica Muhl. var. *hirsuta* (Short) Fern.; Common hairy skullcap	6	CE	o
Scutellaria nervosa Pursh; Smooth creeping skullcap	5	F	r
Scutellaria ovata Hill var. *versicolor* (Nutt.) Fern.; Forest skullcap	6-7	E	o
Stachys tenuifolia Willd.; Smooth hedge nettle	7	DG	r
Synandra hispidula (Michx.) Britt.; White dragonhead	5	F	r
Teucrium canadense L. var. *virginicum* (L.) Eaton; American germander	7	A	r
Lauraceae — Laurel Family			
Lindera benzoin (L.) Blume; Spicebush	3	F	d
Sassafras albidum (Nutt.) Nees; Sassafras	4	A	r
Lythraceae — Loosestrife Family			
Cuphea viscosissima Jacq.; Blue waxweed	7-9	A	o
Magnoliaceae — Magnolia Family			
Liriodendron tulipifera L.; Tulip tree	5	F	o
Malvaceae — Mallow Family			
Malvastrum hispidum (Pursh) Hochr. (*Sphaeralcea angusta*); Yellow globe-mallow	7-8	A	r
§ *Sida spinosa* L.; Prickly sida	6-9	A	o
Menispermaceae — Moonseed Family			
Menispermum canadense L.; Moonseed	6-7	D	o
Molluginaceae — Carpet-Weed Family			
§ *Mollugo verticillata* L.; Carpet-weed	7-10	A	r
Monotropaceae — Indian Pipe Family			
Monotropa uniflora L.; Indian pipe	7	FE	r

Species	Flw	Hab	Rel
Moraceae — Mulberry Family			
Morus rubra L.; Red mulberry	4-5	D	o
Oleaceae — Olive Family			
Fraxinus americana L.; White ash	4-5	DE	c
Fraxinus americana L. var. *blitmoreana* (Beadle) J. Wright *ex* Fern.; Hairy white ash	4-5	E	o
Fraxinus pennsylvanica Marsh. var. *subintegerrima* (Vahl) Fern.; Green ash	5	G	o
Fraxinus quadrangulata Michx.; Blue ash	3-4	E	d
Onagraceae — Evening-Primrose Family			
Circaea quadrisulcata (Maxim.) Franch. & Sav. (*C. canadensis*); Common enchanter's nightshade	6-7	F	o
Epilobium coloratum Biehler; Eastern willowherb	7-9	G	r
Oenothera biennis L.; Common evening-primrose	7-9	A	o
Orobanchaceae — Broom-Rape Family			
Orobanche uniflora L.; Cancer-root	4-5	F	r
Oxalidaceae — Wood Sorrel Family			
Oxalis dillenii Jacq.; Southern yellow wood sorrel	5-9	A	o
Oxalis fontana Bunge var. *bushii* (Small) Hara; Weedy wood sorrel	6-9	A	o
Oxalis grandis Small; Big yellow wood sorrel	6	E	o
Oxalis violacea L.; Violet wood sorrel	4-5	E	r
Papaveraceae — Poppy Family			
Sanguinaria canadensis L.; Bloodroot	3-4	E	c
Stylophorum diphyllum (Michx.) Nutt.; Celandine-poppy	4	F	c
Passifloraceae — Passion-Flower Family			
Passiflora lutea L. var. *glabriflora* Fern.; Passionflower	6-8	C	o
Phytolaccaceae — Pokeweed Family			
Phytolacca americana L.; Pokeberry or pokeweed	7-9	D	c
Plantaginaceae — Plantain Family			
§ *Plantago lanceolata* L.; English plantain	5-9	A	o
Plantago rugelii Decne.; American plantain	7-9	A	o
Plantago virginica L.; Hoary plantain	4-6	A	r

Species	Flw	Hab	Rel
Platanaceae — Plane-Tree Family			
Platanus occidentalis L.; Sycamore	4-5	G	c
Polemoniaceae — Phlox Family			
Phlox divaricata L.; Forest phlox	4-5	F	c
Phlox paniculata L.; Summer phlox	7-9	G	o
Polemonium reptans L.; Spreading Jacob's ladder	4	F	c
Polygalaceae — Milkwort Family			
Polygala senega L. var. *latifolia* T. & G.; Broad-leaved seneca snakeroot	5-7	E	o
Polygonaceae — Smartweed Family			
§ *Polygonum cespitosum* Blume var. *longisetum* (DeBruyn) Stewart; Smartweed	7-9	G	c
Polygonum lapathifolium L.; Dock-leaved smartweed	7-10	G[1]	r
Polygonum aviculare L.; Knotweed	6-10	A	o
Polygonum pensylvanicum L.; Pennsylvania smartweed	6-9	A	o
Polygonum punctatum Ell.; Dotted smartweed	7-9	G	c
Polygonum scandens var. *cristatum* (Engelm. & A. Gray) Gleason; False buckwheat	9-10	C	r
Polygonum scandens var. *scandens* L.; False buckwheat	9-10	G	r
Polygonum virginianum L.; Jumpseed	7-9	D	o
§ *Rumex acetosella* L.; Red sorrell	5-6	A	r
§ *Rumex crispus* L.; Curly dock	5-6	A	o
§ *Rumex obtusifolius* L.; Bitter dock	5-6	A	o
Portulacaceae — Purslane Family			
Claytonia virginica L.; Spring beauty	3-4	F	d
§ *Portulaca oleracea* L.; Common purslane	7-10	A	o
Primulaceae — Primrose Family			
Dodecatheon meadia L.; Eastern shooting star	4-5	EX	o
Samolus valerandi L. ssp. *parviflorus* Raf.; Water pimpernel	6-8	G	o
Pyrolaceae — Shinleaf Family			
Chimaphila maculata (L.) Pursh; Spotted wintergreen	7	C	r

Species	Flw	Hab	Rel
Ranunculaceae — Buttercup Family			
Actaea alba (L.) Miller (*A. pachypoda*); Doll's eyes	5	F	o
Anemone virginiana L.; Tall anemone	7	C	o
Anemonella thalictroides (L.) Spach (*T. thalictroides*); Rue anemone	4	F	c
Aquilegia canadensis L.; Canada columbine	5	E	o
§ *Clematis terniflora* DC. (*C. dioscoreifolia*); Yam-leaved clematis	8-9	A	r
Clematis viorna L.; Hairy leatherflower	6-7	E	r
Clematis virginiana L.; Virgin's bower	8-9	A	r
Delphinium tricorne Michx.; Dwarf larkspur	4	F	c
Hepatica acutiloba DC.; Shape-lobed hepatica	2-4	C	d
Isopyrum biternatum (Raf.) T. & G. (*Enemion biternatum*); False rue anemone	4	F	d
Ranunculus abortivus L.; Small-flowered crowfoot	4	G	o
Ranunculus hispidus Michx.; Hispid buttercup	4	F	o
Ranunculus micranthus Nutt.; Small-flowered crowfoot	4	F	o
Ranunculus recurvatus Poiret; Hooked crowfoot	5	G	o
Thalictrum dioicum L.; Early meadow rue	4	E	c
Rhamnaceae — Buckthorn Family			
Ceanothus americanus L.; New Jersey tea	6	E[2]	r
Rhamnus caroliniana Walt. var. *mollis* Fern.; Carolina buckthorn	6	C	o
§ *Rhamnus cathartica* L.; Common buckthorn	5-6	C	r
§ *Rhamnus citrifolia* (Weston) Hess & Stearn (*R. davurica*); Buckthorn	5-6?	C	r
Rhamnus lanceolata Pursh; Lance-leaved buckthorn	5	CA	o
Rosaceae — Rose Family			
Agrimonia pubescens Wallr.; Downy agrimony	7-8	E	c
Agrimonia rostellata Wallr.; Woodland agrimony	7-8	F	o
§ *Crataegus monogyna* Jacq.; Oneseed hawthorn	5	A	r
§ *Duchesnea indica* (Andrews) Focke; Indian strawberry	4-9	D	o
Fragaria virginiana Duchesne; Thick-leaved wild strawberry	4	A	d

Species	Flw	Hab	Rel
Geum canadense Jacq.; White avens	6-7	D	c
Geum vernum (Raf.) T. & G.; Spring avens	4-6	D	o
Physocarpus opulifolius (L.) Maxim.; Ninebark	6	EX[2]	r
§ *Potentilla norvegica* L.; Strawberry weed	6-8	A	o
§ *Potentilla recta* L.; Sulphur-five-fingers	5-6	A	d
Prunus americana Marsh. var *lanata* Sudw.; Wild plum	4	A	o
Prunus angustifolia Marsh.; Chickasaw plum	4	A	r
§ *Prunus avium* L.; Sweet cherry	4-5	E	r
Prunus serotina Ehrh.; Wild black cherry	5	D	d
Prunus virginiana L.; Chokecherry	5	B	o
§ *Rosa canina* L.; Dog rose	5-6	A	r
Rosa carolina L.; Pasture rose	6	E	c
§ *Rosa multiflora* Thunb.; Multiflora rose	5	D	c
Rosa setigera Michx.; Climbing prairie rose	6	A	o
Rubus pensilvanicus Poiret (*sensu lato*); Pennsylvania blackberry	5-6	A	d
Rubus occidentalis L.; Black raspberry	4-6	A	c
Rubiaceae — Madder Family			
Galium aparine L.; Cleavers	5-6	D	d
Galium circaezans Michx.; Forest bedstraw	6	E	c
Galium triflorum Michx.; Sweet-scented bedstraw	5-8	F	c
Hedyotis purpurea (L.) T. & G. var. *calycosa* (A. Gray) Fosb. (*Houstonia lanceolata*); Purple sweet-ear	6-7	D	o
Rutaceae — Rue Family			
Ptelea trifoliata L.; Common hoptree	5-6	E	o
Zanthoxylum americanum Miller; Common prickly ash	4-5	A	r
Salicaceae — Willow Family			
§ *Populus alba* L.; White or silver poplar	4	D	r
Salix exigua Nutt.; Sandbar willow	4	GA	r
Salix nigra Marsh.; Black willow	4	GA	o
Saxifragaceae — Saxifrage Family			
Heuchera americana L.; Common alumroot	5-7	E	o

Species	Flw	Hab	Rel
Heuchera villosa Michx. var. *macrorhiza* (Small) C. Rosend.; Maple-leaved alumroot	7-9	EFX	c
Mitella diphylla L.; Bishop's cap	4-5	F	o
Saxifraga virginiensis Michx.; Early saxifrage	3-4	FX	c
Scrophulariaceae — Figwort Family			
Aureolaria flava (L.) Farw.; Smooth false foxglove	7-8	E^2	r
Collinsia verna Nutt.; Eastern blue-eyed Mary	5	FD	c
Dasystoma macrophylla (Nutt.) Raf.; Mullein foxglove	7	C	r
Mimulus alatus Ait.; Sharpwing monkeyflower	7-8	G	o
Penstemon calycosus Small; Eastern beard-tongue	5-6	D	o
Penstemon hirsutus (L.) Willd.; Northeastern beard-tongue	5	EX	o
§ *Verbascum blattaria* L.; Moth mullein	6-8	A	o
§ *Verbascum thapsus* L.; Common mullein	6-8	A	o
§ *Veronica arvensis* L.; Corn speedwell	3-7	A	c
§ *Veronica serpyllifolia* L.; Thyme-leaved speedwell	4-6	A	o
Solanaceae — Nightshade Family			
§ *Datura stramonium* L.; Jimson-weed	7-9	A	r
Physalis heterophylla Nees.; Clammy ground cherry	6-8	A	o
Physalis longifolia Nutt. var. *subglabrata* (Mack. & Bush) Cronq.; Longleaf ground cherry	6-8	A	o
§ *Solanum nigrum* var. *virginicum* L.; Black nightshade	6-9	A	o
Staphyleaceae — Bladder-Nut Family			
Staphylea trifolia L.; Bladdernut	4	F	d
Thymelaeaceae — Mezereum Family			
Dirca palustris L.; Leatherwood	3	GF	r
Tiliaceae — Linden Family			
Tilia americana L.; Basswood	6-7	F	c
Tilia heterophylla Vent.; White basswood	6-7	F	o
Ulmaceae — Elm Family			
Celtis occidentalis L.; Northern hackberry	5?	D	d
Celtis tenuifolia Nutt.; Dwarf hackberry	5?	C	o
Celtis tenuifolia x *occidentalis*; Dwarf hackberry and northern hackberry hybrid	5?	C	o

Species	Flw	Hab	Rel
Ulmus americana L.; American or white elm	2-3	G	c
Ulmus rubra Muhl.; Slippery or red elm	3	F	c
Ulmus thomasii Sargent; Rock elm	5	E	c
Urticaceae — Nettle Family			
Boehmeria cylindrica (L.) Swartz; False nettle	7-9	G	c
Laportea canadensis (L.) Weddell; Wood nettle	7	G	o
Parietaria pensylvanica Muhl.; Pillitory	5-8	EY	o
Pilea pumila (L.) A. Gray; Clearweed	7-9	G	c
Urtica chamaedryoides Pursh; Stinging nettle	3-5	F	o
Valerianaceae — Valerian Family			
Valeriana pauciflora Michx.; Long-tube valerian	5	F	o
§ *Valerianella locusta* (L.) Betcke (*V. olitoria*); European cornsalad	4-5	A	r
Verbenaceae — Vervain Family			
Phryma leptostachya L.; Lopseed	7	F	o
Verbena simplex Lehm.; Narrow-leaved vervain	5-6	A	o
Verbena urticifolia L.; White vervain	6-8	A	o
Violaceae — Violet Family			
Hybanthus concolor (T. Forster) Spreng.; Green violet	4-5	F	o
? *Viola canadensis* L.; Tall white violet	4-5	F	r
Viola papilionacea Pursh; Smooth blue stemless violet	4	D	c
Viola pubescens var. *pubescens* Ait.; Yellow forest violet	4	F	o
Viola pubescens var. *eriocarpa* (Schwein.) Russell (*V. eriocarpa*); Smooth yellow-stemmed violet	4	F	o
Viola rafinesquii Greene; Wild pansy	4	A	o
Viola sororia Willd.; Dooryard violet	4	F	c
Viola striata Ait.; Creamy violet	4-5	D	d
Viscaceae — Christmas-Mistletoe Family			
Phoradendron serotinum (Raf.) Johnston (*P. flavescens*); American Christmas-mistletoe	9	D	r
Vitaceae — Grape Family			
Parthenocissus quinquefolia (L.) Planchon; Virginia creeper	5-6?	DF	d

Species	Flw	Hab	Rel
Vitis vulpina L.; Frost grape	5-6	DF	c
MONOCOTYLEDONAE (Monocotyledons)			
Alismataceae — Water-Plantain Family			
? *Sagittaria australis* (Smith) Small; Appalachian arrowhead	7-8	G	r
Araceae — Arum Family			
Arisaema dracontium (L.) Schott; Green dragon	5-6	D	r
Arisaema triphyllum var. *triphyllum* (L.) Schott (*A. atrorubens*); Jack-in-the-pulpit	5	F	o
Commelinaceae — Spiderwort Family			
§ *Commelina communis* L.; Common dayflower	7-9	AG	o
Tradescantia subaspera Ker Gawler; Wide-leaved spiderwort	6	DF	c
Cyperaceae — Sedge Family			
Carex albicans Willd. var. *emmonsii* (Dewey) Rettig.; Sedge	4-6	E	o
Carex albursina Sheldon; Sedge	4-6	F	c
Carex amphibola var. *amphibola* Steud.; Sedge	5-6	D	o
Carex amphibola var. *turgida* Fern. (*C. grisea*); Sedge	5-6	G	o
Carex annectens var. *annectens* Bickn.; Sedge	6-7	A	o
Carex blanda Dewey; Sedge	4-6	D	c
Carex careyana Torr.; Sedge	5-6	F	o
Carex cephalophora Muhl. var. *mesochorea* (Mack.) Gleason; Sedge	5-6	A	o
Carex communis Bailey; Sedge	5-6	F	o
Carex complanata Torr. & Hook. var. *hirsuta* (Bailey) Gleason (*C. hirsutella*); Sedge	5-7	A	o
Carex conjuncta F. Boott; Sedge	6	GA	r
Carex eburnea F. Boott; Sedge	5-7	EX	o
Carex frankii Kunth; Sedge	6-8	GA	o
Carex granularis Muhl.; Sedge	5-6	GA	r
? *Carex hitchcockiana* Dewey; Sedge	5-6	E	r
Carex jamesii Schw.; Sedge	5-6	D	d
Carex laevivaginata (Kuken.) Mack.; Sedge	5-6	GA	r
Carex laxiculmis Schw.; Sedge	5-6	GF	r

Species	Flw	Hab	Rel
Carex laxiflora Lam.; Sedge	4-6	F	c
Carex molesta (Dewey) Mack.; Sedge	6-7	GA	r
Carex muhlenbergii Schk. var. *enervis* Boott; Sedge	6-7	A	o
Carex oligocarpa Schk.; Sedge	5-6	D	d
Carex pensylvanica var. *pensylvanica* Lam.; Sedge	4-6	E	c
Carex plantaginea Lam.; Sedge	4-6	F	r
Carex platyphylla Carey; Sedge	4-6	E	o
Carex retroflexa var. *retroflexa* Muhl.; Sedge	5-6	C	o
Carex rosea Schk. *ex* Willd. (*C. convoluta*); Sedge	5-6	F	o
Carex sparganioides var. *sparganioides* Muhl.; Sedge	6-7	D	o
? *Carex striatula* Michx.; Sedge	5-6	E	o
Carex vulpinoidea Michx.; Sedge	6-7	GA	o
Cyperus strigosus L.; False nutsedge	8-9	A	o
Scirpus atrovirens var. *atrovirens* Willd.; Black bulrush	5-6	G	o
Dioscoreaceae — Yam Family			
§ *Dioscorea batatas* Decne.; Cinnamon-vine		G	o
Dioscorea quaternata (Walt.) Gmelin; Colic-root	5	F	c
Iridaceae — Iris Family			
§ *Belamcanda chinensis* (L.) DC.; Blackberry lily	6-7	A	r
Sisyrinchium angustifolium Miller (*S. graminoides*); Blue-eyed grass	5-6	A	o
Juncaceae — Rush Family			
Juncus tenuis var. *tenuis* Willd.; Path rush	6-8	D	o
Liliaceae — Lily Family			
Allium burdickii (Hanes) A.G. Jones (*A. tricoccum* var. *burdickii*); Ramps or wild leek	5-6	F	o
Allium canadense L.; Onion	5-7	A	c
Allium cernuum Roth; Nodding onion	5-6	GEX	o
Allium tricoccum Ait.; Ramps or wild leek	6-7	F	d
§ *Allium vineale* L.; Field-garlic	5-7	AD	o
Camassia scilloides (Raf.) Corey; Wild hyacinth	5	F	c
Erythronium albidum Nutt.; White trout lily	3	E	o
Erythronium americanum Ker Gawler; Yellow trout lily	4	F	d

	Species	Flw	Hab	Rel
	Lilium michiganense Farw.; Michigan lily	6-7	G[3]	r
§	*Ornithogalum umbellatum* L.; Star-of-Bethlehem	5	F	o
	Polygonatum biflorum var. *biflorum* (Walt.) Ell.; Solomon's seal	5	F	c
	Polygonatum biflorum var. *commutatum* (R. & S.) Dietr.; Solomon's seal	6	D	o
	Polygonatum pubescens (Willd.) Pursh; Solomon's seal	5	F	c
	Smilacina racemosa (L.) Desf.; False Solomon's seal	5	F	c
	Trillium flexipes Raf.; Bent trillium	4	F	o
	Trillium sessile L.; Toadshade	4	D	c
	Uvularia grandiflora Smith; Large bellwort	4	F	c
	Uvularia perfoliata L.; Small bellwort	4-5	E	o
	Orchidaceae — Orchid Family			
	Aplectrum hyemale (Muhl.) Torr.; Puttyroot	5-6	C	r
	Corallorhiza odontorhiza (Willd.) Nutt.; Autumn coral-root	8-9	D[3]	r
	Goodyera pubescens (Willd.) R. Brown; Downy rattlesnake plantain	7	F	r
	Liparis liliifolia (L.) Richard; Large twayblade	6	C	r
	Spiranthes ovalis Lindley; Oval ladies'-tresses	9-10	C	r
	Tipularia discolor (Pursh) Nutt.; Crane-fly orchid	8	F	r
	Poaceae — Grass Family			
	Andropogon gerardii Vitman; Big bluestem	8-9	B	d
	Andropogon virginicus L.; Broom sedge	8-9	A	o
§	*Arrhenatherum elatius* (L.) J. & C. Presl; Tall oatgrass	5	A	o
	Brachyelytrum erectum (Schreber) Beauv.; Little-glume wood-grass	6-8	F	o
	Bromus pubescens Muhl.; Bromegrass	6-7	E	c
§	*Bromus inermis* Leysser; Smooth brome	5-6	A	o
§	*Bromus japonicus* Thunb.; Japanese chess	6-7	A	d
	Chasmanthium latifolium (Michx.) Yates (*Uniola latifolium*); Wild oats	6-8	BE	d
	Cinna arundinacea L.; Common woodreed	7-9	G	c
§	*Dactylis glomerata* L.; Orchard grass	5-6	A	c
	Danthonia spicata (L.) Beauv.; Poverty oats	5-6	E	c

	Species	Flw	Hab	Rel
	Diarrhena americana P. Beauv.; Two-stamen wood-grass	7-8	E	c
§	*Digitaria sanguinalis* (L.) Scop.; Northern crabgrass	6-9	A	o
§	*Echinochloa crusgalli* (L.) Beauv.; Barnyard grass	6-9	AG	o
§	*Eleusine indica* (L.) Gaertn.; Yard-grass	7-9	A	o
	Elymus hystrix var. *bigeloviana* (Fern.) Gl.; Hairy bottlebrush grass	6-8	E	r
	Elymus hystrix var. *hystrix* L. (*Hystrix patula*); Bottlebrush grass	6-8	E	d
	Elymus hystrix x *virginicus*; Bottlebrush grass and wild rye hybrid	6-7	DA	r
	Elymus sp. nov. (R. Brooks, in prep.); Early wild rye	5-6	DG	o
	Elymus villosus Muhl.; Downy wild rye	6-7	DC	d
	Elymus virginicus var. *hirsutiglumis* (Scribner) Fern.; Hirsute wild rye	7-8	B	o
	Elymus virginicus var. *virginicus* L.; Virginia wild rye	6-8	GA	c
§	*Elytrigia repens* (L.) Nevski (*Agropyron repens*); Quackgrass	6	A	r
§	*Eragrostis cilianensis* (All.) Janchen (*E. megastachya*); Stinkgrass	6-8	A	o
	Eragrostis pectinacea (Michx.) Nees; Carolina lovegrass	7-8	A	o
§	*Festuca elatior* L. (*F. arundinacea*); Tall or alta fescue	5-6	A	d
	Festuca subverticillata (Pers.) Alexeev. (*F. obtusa*); Nodding fescue	5-6	DF	c
	Glyceria striata (Lam.) Hitchc.; Fowl mannagrass	5-6	G	d
	Hordeum pusillum L.; Little barley	5	A	o
	Leersia oryzoides (L.) Swartz; Rice cutgrass	8-9	G[1]	o
	Leersia virginica Willd.; White grass	7-8	D	c
	Melica mutica Walt.; Two-flower melic grass	4-5	E	o
§	*Microstegium vimineum* (Trin.) Camus (*Eulalia viminea*); Japanese grass	9-10	CG	c
	Muhlenbergia frondosa (Poiret) Fern.; Muhly	7-9	GB	o
?	*Muhlenbergia schreberi* Gmelin; Nimblewill	7-10	A	r?
	Muhlenbergia sobolifera (Muhl.) Trin.; Muhly	7-9	E	c
	Panicum anceps Michx.; Panic grass	7-8	A	r

	Species	Flw	Hab	Rel
	Panicum boscii Poiret; Panic grass	5-7	EC	c
	Panicum capillare var. *campestre* Gattinger (*P. gattingeri*); Witchgrass	8-9	A	o
	Panicum capillare var. *capillare* L.; Witchgrass	8-9	A	o
	Panicum clandestinum L.; Panic grass	5-8	AG	c
	Panicum dichotomiflorum Michx.; Panic grass	8-9	A	o
	Panicum flexile (Gattinger) Scribner; Wiry witchgrass	8-9	ACX	c
	Panicum lanuginosum Ell. var. *fasciculatum* (Torr.) Fern. (*P. acuminatum*); Panic grass	5-8	AC	o
§	*Phleum pratense* L.; Timothy	6-7	A	c
§	*Poa annua* L.; Speargrass	4-5	A	o
	Poa cuspidata Nutt.; Bluegrass	3-4	E	c
§	*Poa pratensis* L. (and *P. angustifolia* L. ?); Kentucky bluegrass	4-6	A	d
	Poa sylvestris Gray; Forest bluegrass	4-5	D	c
	Schizachyrium scoparium (Michx.) Nash (*Andropogon scoparius*); Little bluestem	8-9	B[1]	r
§	*Setaria viridis* (L.) Beauv.; Green foxtail	7-9	A	o
	Sorghastrum nutans (L.) Nash; Indian grass	8-9	B[1]	r
§	*Sorgum halepense* (L.) Pers.; Johnson grass	6-8	A	o
	Sphenopholis nitida (Biehler) Scribner; Wood wedgegrass	4-5	E	o
	Tridens flavus (L.) Hitchc. (*Triodia flava*); Purpletop	7-8	A	c
Smilacaceae — Catbrier Family				
	Smilax bona-nox var. *bona-nox* L.; Tough-leaved greenbrier	5-6	E	o
	Smilax bona-nox var. *hederaefolia* (Beyrich) Fern.; Tough-leaved greenbrier	5-6	E	o
?	*Smilax glauca* Walt.; Glaucous greenbrier	5-6	A	r
	Smilax herbacea L. var. *lasioneura* (Small) Rydb.; Climbing carrion-flower	6	D	o
	Smilax hispida Muhl.; Bristly greenbrier	5-6	D	o
	Smilax rotundifolia L.; Catbrier	4-6	C	o
Typhaceae — Cattail Family				
	Typha latifolia L.; Common cattail	6-8	G	o

Not listed is *Trillium recurvatum* Beck. A 1961 student collection exists with the locality given as "Raven Run." This specimen is most likely mislabelled, because this Western species is otherwise unknown from the region.

DESCRIPTION OF VEGETATION TYPES

OLD FIELDS

Species largely restricted to old fields (A in Figure 2) comprise approximately 32% of the total flora, but only 22% of the native flora. These species also include 43% of herbaceous species with post-June flowering, but only 15% of those with pre-July flowering.

Open areas on the ridges typically have the McAfee soil series and are dominated by Poaceae, Asteraceae, Fabaceae, and Rosaceae. Abundant Poaceae are *Bromus japonicus* and *Festuca elatior*; others include *Phleum pratense, Poa pratensis, Dactylis glomerata, Tridens flavus,* and *Panicum clandestinum.* Abundant Asteraceae include *Solidago altissima* and *Aster pilosus*; others include *Achillea millefolium, Chrysanthemum leucanthemum, Tragopogon dubius, Vernonia gigantea, Verbesina occidentalis, Rudbeckia* spp. (especially *R. triloba*), *Cirsium discolor,* and *Erigeron* spp. (especially *E. annuus*). Among the Fabaceae, *Trifolium campestre* is most abundant; others include *Melilotus* spp., *Vicia villosa,* and *Desmodium perplexum.* Frequent Rosaceae are *Fragaria virginiana* and *Potentilla recta.* Other frequent species are *Monarda fistulosa, Blephilia ciliata, Apocynum cannabinum, Asclepias syriaca, Geranium carolinianum, Daucus carota, Torilis arvensis,* and *Dianthus armeria.* Small areas of bare rock are colonized by *Sedum pulchellum, Arenaria serpyllifolia, Croton monanthogynus,* and *Echium vulgare.*

Common woody pioneers include *Rubus pensilvanicus, Symphoricarpos orbiculatus, Rhus glabra, Robinia pseudoacacia,* and *Vitis vulpina,* all of which are able to spread widely by root sprouts or decumbent stems. Other frequent woody pioneers include *Juniperus virginiana, Gleditsia triacanthos, Prunus serotina, Ulmus americana, Campsis radicans, Toxicodendron radicans,* and *Lonicera japonica.* Vines as well as *Juniperus virginiana* are particularly abundant in the field under the power lines, where herbicides have often been applied in the past.

Three intergrading types of old fields may be recognized though some areas are mixed or otherwise difficult to classify.

Recently Plowed or Disked Areas (A1). During 1980-1986, about half of the total field area was disked to reinitiate secondary succession, while the rest was mowed or abandoned. Disked areas now have abundant *Trifolium campestre.* Also frequent are *Melilotus officinalis, Bromus japonicus, Festuca elatior, Solidago altissima, Aster pilosus, Fragaria virginiana,* and *Potentilla recta.* Annual or biennial species are relatively frequent as a group, including *T. campestre, M. officinalis, B. japonicus,* several Asteraceae (*Ambrosia* spp., *Erigeron* spp., *Carduus nutans, Cirsium discolor,* and *Bidens* spp.), Caryophyllaceae (*Dianthus armeria, Stellaria* spp., and *Cerastium* spp.), *Daucus carota,* and *Triodanis perfoliata.* In the Raven Run area, *Ambrosia* spp. and *Erigeron* spp. are often dominant during the first 1-2 years after plowing. Among woody pioneers, *Rubus pensilvanicus* and *Prunus serotina,* both with sweet warm season

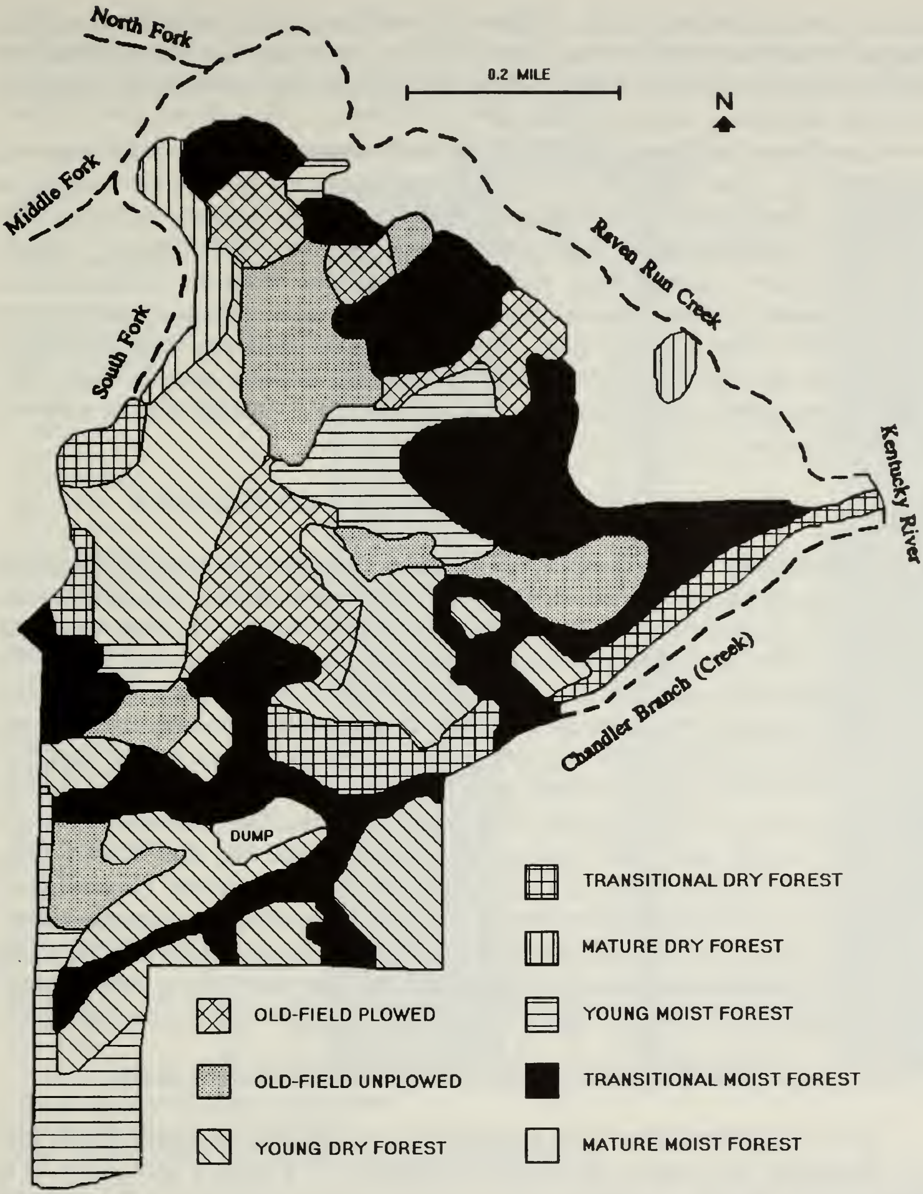

Figure 2. Raven Run Nature Sanctuary plant communities (see text for description of forest types): A1 = old-field plowed; A2-A3 = old-field unplowed; C1 = young dry forest; C2 = transitional dry forest; D1 = young moist forest; D2-D3 = transitional moist forest; E1-E2 = mature dry forest; and F1-F2 = mature moist forest.

fruit, are notably more frequent than in other areas, whereas *Symphoricarpos orbiculatus,* with relatively unrewarding fruit, is much less abundant.

Old Pastures or Mowed Grassy Areas (A2). Parts of the fields have probably been sown with various pasture grasses in the past or have become grassy because of repeated mowing, such as near the barns, parking lots, and trails through fields. *Festuca elatior* is often dominant, and other perennial grasses are frequent. However, little or no annual *Bromus japonicus* was found. Frequent herbs include *Trifolium campestre, Monarda fistulosa, Achillea millefolium, Solidago altissima,* and *Aster pilosus.*

Less Disturbed Brushy Fields (A3). In areas abandoned for 5-10 years and with mowing at no more than 1-3 year intervals, woody species have begun to dominate. Ten to 20% of the field area is in this condition, typically with abundant *Solidago altissima* and *Poa pratensis.* Also frequent are *Festuca elatior, Tridens flavus, Panicum clandestinum, Achillea millefolium, Monarda fistulosa,* and, locally, *Blephilia ciliata. Monarda fistulosa* appears to have increased greatly during the past few years at Raven Run. Major woody invaders are *Symphoricarpos orbiculatus* and, in taller thickets, *Rhus glabra* and *Robinia pseudoacacia.* The other woody species noted above are also frequent, plus patches of *Rosa setigera, Prunus americana,* and *Cornus drummondii.*

GRASSY VEGETATION ON ROCKY RIVERBANKS

The Kentucky River floodplain (B in Figure 2) supports an unusual vegetation type that is largely restricted to steep slopes in bends of the river where rock outcrops are exposed near the water level. Instead of forest, a 1-10 m wide strip of grassy or brushy vegetation occurs. *Andropogon gerardii* is abundant in the open, and *Chasmanthium latifolium* is abundant in the brushy transition to forest above the outcrops. A rare goldenrod, *Solidago rupestris,* is locally frequent and restricted to such sites. This vegetation type occurs on the east-facing bank just north of Raven Run Creek. Frequent woody species in the brushy transition include *Rhus aromatica, Ostrya virginiana, Juniperus virginiana, Quercus muehlenbergii,* and *Acer saccharum.* This site might possibly be the one that Robert Peter described in 1834 as a "rocky bank, Raven Creek, Kentucky River" (MacFarlane, 1979). Peter collected *Sorghastrum nutans* and *Schizachyrium scoparium* here, but these species are currently unknown in Fayette County. Also notable along the river are *Justicia americana* and *Leersia oryzoides,* which form patches at the outer edge of gravel bars, including the island by the mouth of Raven Run Creek.

SUCCESSIONAL FOREST ON DRY OR ERODED SITES

Occurring primarily on west to south-facing, moderate to gentle slopes with the Fairmount soil series, this vegetation type (C in Figure 2 and Table 1) is dominated by *Juniperus virginiana,* the most common pioneering tree of abandoned pastures on dry or eroded soil. Two intergrading types can be distinguished.

Young *Juniperus* Forest (C1). Red cedar trees located in this habitat are generally no more than 10-20 cm dbh (diameter breast height) and about 30-50 years old. Frequent associates are *Gleditsia triacanthos* and, in the understory, *Fraxinus americana* and, occasionally, *F. quadrangulata.* Other trees include *Juglans nigra, Celtis occidentalis, Ulmus rubra, U. americana,* and occasional saplings of *Quercus muehlenbergii* and *Q. shumardii.* In the shrub layer, *Lonicera maackii* is abundant, while *Symphoricarpos orbiculatus* is locally abundant, especially in more open areas. In denser stands, mosses (especially *Thuidium* spp.) are abundant, and the only frequent vascular herb is *Asplenium platyneuron.*

Table 1. Basal areas and other quantitative data illustrating tree species composition from 17 circular plots. C1 and C2 are *Juniperus* dominated stands; D-F are older mesophytic stands. The species order approximates the general successional trends in the region (Campbell, 1980).

	Forest Type and Plot Number																
Species	C1		C2				D2			E1	E2				F1		
	1	6[a]	5	7[a]	3	18[a]	2[b]	10	8[b]	17	15	13	14	12	16	9	11
Platanus occidentalis	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
Juniperus virginiana	112	99	19	54	24	75	24	22	—	15	44	—	—	2	6	—	—
Cercis canadensis	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Gleditsia triacanthos	53	15	23	3	—	—	—	—	—	3	—	9	—	—	—	—	—
Robinia pseudoacacia	—	—	—	—	—	—	—	2	—	—	—	—	—	—	—	—	—
Juglans nigra	20	2	13	31	3	—	6	23	7	—	—	5	—	—	—	—	—
Prunus serotina	—	—	16	—	—	—	—	—	10	7	—	—	—	—	—	—	—
Carya laciniosa	17	—	7	12	2	—	—	—	—	9	—	20	—	2	—	—	—
Carya ovata	8	5	18	3	4	—	—	—	—	—	7	—	5	4	—	—	—
Ulmus americana	—	—	—	12	—	—	5	17	—	—	—	—	—	—	—	—	—
Ulmus rubra	—	—	11	13	1	—	2	—	2	—	—	10	15	2	—	—	9
Ulmus thomasii	—	—	—	—	—	9	—	—	18	—	—	—	2	—	—	—	—
Fraxinus americana	—	—	11	9	56	28	28	35	19	—	—	9	24	—	59	—	7
Fraxinus quadrangulata	—	—	—	—	2	13	6	—	9	46	4	26	26	5	—	—	—
Quercus muehlenbergii	3	1	12	25	26	29	28	—	—	61	22	33	20	64	15	16	—
Gymnocladus dioica	—	—	—	—	—	—	—	23	—	—	—	—	—	—	—	—	—
Aesculus glabra	—	—	7	5	2	—	9	55	—	5	2	10	15	1	8	—	—
Celtis occidentalis	—	—	—	—	—	—	10	4	42	22	—	—	—	—	—	—	18
Carya cordiformis	—	—	—	4	22	—	40	—	6	37	—	—	—	50	—	33	—
Acer saccharum/nigrum	—	10	23	40	30	11	11	—	35	2	37	32	30	28	60	52	70
Quercus shumardii	—	—	—	—	1	—	—	—	26	30	19	—	85	12	55	—	—
Quercus velutina	—	—	—	—	—	—	—	—	—	3	—	—	—	—	—	—	—
Liriodendron tulipifera	—	—	—	—	—	—	—	—	—	—	26	—	—	—	—	—	—
Ostrya virginiana	—	—	—	—	—	7	1	—	1	—	—	3	6	—	2	1	—
Carpinus caroliniana	—	—	—	—	—	—	1	—	—	—	—	—	—	3	1	—	—
Tilia spp.	—	—	—	—	—	1	9	—	5	—	12	15	—	—	16	65	7
Aesculus flava	—	—	—	—	—	4	—	—	—	—	—	8	—	—	10	20	5
Quercus rubra	—	—	5	—	—	—	—	—	—	—	—	—	—	—	—	28	111
Fagus grandifolia	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	2
Total Basal Area[c]	213	142	165	208	173	178	182	181	180	240	173	180	228	173	232	215	229
Tree Density[c]	863	637	622	722	693	440	651	622	400	693	651	651	566	566	523	439	509
Approx. Age (years)	40s	40s	40s	40s	40s	50s	50s	50s	40s	50s	40s	50s	50s	50s	90s	60s	90s
Slope Aspect[c]	NW	WNW	WNW	SE	SSE	NNE	SW	B	B	ENE	NNE	NE	ENE	SE	NNE	B	NNE

[a] Plot on relatively xeric upper slope position.

[b] Plot on relatively gentle slope position.

[c] Basal area is in units of dm^2/ha; density is in stems/ha; B=bottom.

In more open areas, frequent species include *Toxicodendron radicans, Campanula americana, Glechoma hederacea,* and *Elymus villosus.* Minor species include *Sedum* spp., *Torilis arvensis,* and *Eupatorium rugosum.*

Older *Juniperus* Forest and Transition to *Quercus* (C2). This vegetation type generally has canopy trees of 20-40 cm dbh. Although *Juniperus virginiana* is still dominant, and *Gleditsia triacanthos* often remains, frequent invading trees of *Quercus muehlenbergii* (and an occasional *Q. shumardii*), *Fraxinus americana* (with some *F. quadrangulata*), *Ulmus rubra,* and *Acer saccharum* also occur. Other trees are *Juglans nigra, Carya ovata,* and, less often, *C. laciniosa. Cercis canadensis* and *Ostrya virginiana* occur in the understory. *Lonicera maackii* remains frequent, though less than in younger stands, and *L. japonica* patches occur in more open areas. Herb cover is greater than in young red cedar stands and is highly variable in composition. Locally abundant species include *Delphinium tricorne, Senecio obovatus, Aster shortii,* and *Elymus villosus.* Other species present are *Anemonella thalictroides, Ranunculus micranthus, Claytonia virginica, Viola sororia, Geum canadense, Trillium sessile,* and *Liparis liliifolia.*

SUCCESSIONAL FOREST ON MOIST SITES WITH GENTLER SLOPES

This habitat (D in Figure 2 and Table 1) occurs widely on deeper soils in the McAfee series and locally on shallower soils of north- to east-facing slopes. Most canopy trees are only 25-75 years old, and the forest has probably been much disturbed by partial cutting and grazing. Three types can be distinguished.

Robinia-Prunus **Forest and Transitions (D1).** This vegetation type generally has canopy trees no more than 20-40 cm dbh and about 30-50 years old. *Robinia pseudoacacia* is an abundant invader, both by seed and by root sprouts from forest edges and isolated trees. *Prunus serotina* is generally present though rarely abundant. Also common in some areas are *Juglans nigra, Ulmus americana, Celtis occidentalis, Fraxinus americana,* and *Gleditsia triacanthos. Aesculus glabra* is scattered in the understory. The smaller shrubs, *Symphoricarpos orbiculatus* and *Rubus* spp., and the vines, *Parthenocissus quinquefolia* and *Vitis vulpina,* are common in places. *Elymus villosus* is generally abundant. Also frequent are *Phytolacca americana, Stellaria media, Geum canadense, G. vernum, Viola papilionacea, V. striata, Lamium purpureum, Phacelia purshii, Galium aparine, Aster ontarionis,* and *Panicum clandestinum.*

Juglans-Celtis-Fraxinus **Forest (D2).** This forest generally has larger trees, up to 50-70 cm dbh, and appears older or less frequently disturbed than the preceding type (D1). While *Juglans nigra* and *Celtis occidentalis* are the dominant trees, other frequent trees include *Fraxinus americana, Ulmus rubra, U. americana, Quercus muehlenbergii, Q. shumardii, Carya laciniosa, Prunus serotina, Robinia pseudoacacia,* and *Acer negundo. Aesculus glabra* and *Gymnocladus dioicus* are occasionally present. *Acer nigrum* and *A. saccharum* are generally absent in the canopy but often common in the understory. The exotic shrub, *Lonicera maackii,* is frequent in some areas, more so than in the *Robinia-Prunus* forest. *Symphoricarpos orbiculatus* is less abundant, and *Rubus* spp. are generally absent. The herb layer is generally dominated by *Elymus* spp., especially *E. villosus. Chaerophyllum procumbens, Cryptotaenia canadensis,* and *Osmorhiza longistylis* are also frequent. The flora combines several species characteristic of both *Robinia-Prunus* (D1) and *Acer nigrum* (F1) forest types.

Mixture with ***Juniperus*** **Forest (D3).** In several areas, successional forest with *Robinia, Prunus, Juglans,* and *Celtis* has an admixture of *Juniperus* and *Gleditsia,* the latter two being common, grazing-resistant pioneers in abandoned pastures of this region. *Lonicera* spp. are frequent, as in stands dominated by *J. virginiana. Elymus villosus* remains abundant, but in some areas, *Eupatorium rugosum,* a grazing-resistant species (Bratton, *et al.,* 1982), is abundant, and *Campanula americana* is frequent.

MATURE FOREST ON DRY (SUBXERIC) SITES

These sites (E in Figure 2 and Table 1) are on steeper, south- to west-facing slopes and on some upper slopes or narrow ridges with other aspects. Succession on regional sites often involves shifts from subxeric to mesic forest types (Campbell, 1980, 1987). In particular, *Acer saccharum* can invade the subcanopy of some *Quercus-Fraxinus* forest within 50-100 years. The two primary types are the *Quercus-Fraxinus-Juniperus* forest (E1) and the *Quercus-Fraxinus-Acer saccharum* mixed forest (E2).

***Quercus-Fraxinus-Juniperus* Forest (E1).** On drier, southwest- to south-facing slopes, narrow ridges, and points, *Quercus muehlenbergii, Fraxinus quadrangulata,* and *Juniperus virginiana* are locally dominant. However, *Acer saccharum* is generally frequent in the understory. Other woody species include *Q. shumardii, F. americana, Ostrya virginiana,* and *Viburnum rafinesquianum.* On steeper slopes, additional woody plants include *Ulmus thomasii* and *Staphylea trifolia.* In the variable herb layer, frequent species include *Thalictrum dioicum, Solidago ulmifolia, Polygonatum biflorum, Erythronium albidum, Elymus hystrix, Diarrhena americana, Poa cuspidata, Bromus pubescens, Muhlenbergia sobolifera,* and *Carex* spp. (especially Section *Montanae*). Also typical are *Arenaria patula, Euphorbia commutata, Dodecatheon meadia, Aster shortii,* and *Solidago sphacelata.* On the dry upper slopes just north of the mouth of Raven Run Creek is *Ceanothus americanus, Zizia aptera, Frasera caroliniensis, Triosteum aurantiacum,* and *Helianthus microcephalus.* On gentler upper slopes, ridges, and points, or on ridge crests, additional woody species include *Carya ovata* and, on rocky ledges, *Lonicera dioica. Elymus hystrix* is abundant here, and more mesophytic species are often present, especially *Erythronium americanum, Hepatica acutiloba, Corydalis flavula, Saxifraga virginiensis,* and *Trillium sessile.*

Mixture of *Quercus-Fraxinus* and *Acer saccharum* Forest (E2). On many slopes, the forest is intermediate between the *Quercus-Fraxinus-Juniperus* type (E1) and the *Acer saccharum* type (F1). The variety in herbaceous composition is considerable. Typical mesophytic dominants, such as *Stellaria corei* and *Erythronium americanum,* are locally common. In some distinct areas, *Sanguinaria canadensis* and *Jeffersonia diphylla* are also frequent and appear to have spread within the past 15 years, especially upstream along the South Fork trail. Also frequent in this transition are *Hepatica acutiloba, Uvularia grandiflora, Euonymus obovatus, Silene virginica, S. caroliniana, Allium canadense* (in seeps or gullies), and species typical of drier forest. *Claytonia virginica* occurs occasionally, but virtually no *Asarum canadense, Isopyrum biternatum, Podophyllum peltatum, Sedum ternatum, Polymnia canadensis,* or *Allium tricoccum* are found.

MATURE FOREST ON MOIST (MESIC) SITES

This vegetation type (F in Figure 2 and Table 1) is concentrated on moist, steeper slopes, except for those with south- to southwest-facing aspects. Soils are shallow and mapped as rockland or the Fairmount soil series. Before settlement, similar forest may have occurred on gentler slopes above the ravines with soils of the McAfee series (see F2) and on a few bottomland terraces with soils of the Huntingdon series. However, the remaining forest on gentler slopes has been disturbed, and most trees are less than 50 years old. The two main types are the *Acer saccharum* forest on steeper slopes (F1) and the *A. nigrum* forest on gentler slopes (F2).

***Acer saccharum* Forest on Steeper Slopes (F1).** The most mesic sites occur on north- to northeast-facing slopes below cliffs. *Acer saccharum* is generally dominant, though often intermixed with *A. nigrum.* Other woody species include *Tilia* spp., *Aesculus* spp., *Quercus rubra, Q. shumardii, Fraxinus americana, Ulmus rubra, Carya cordiformis, C. laciniosa, Celtis occidentalis, Juglans nigra, Carpinus caroliniana, Lindera benzoin,* and *Hydrangea arborescens.* Near cliffs and on drier aspects, an admixture of *Q. muehlenbergii, F. quadrangulata, U. thomasii,* and *Staphylea trifolia* often occurs. Abundant herbaceous species are generally *Stellaria corei* and *Erythronium americanum.* Frequent herbs, although occasionally locally abundant, include *Asarum canadense, Isopyrum biternatum, Dicentra canadensis, Claytonia virginica, Uvularia grandiflora, Allium tricoccum,* and *Carex albursina.* Occasional, though characteristic, herbs include *Cystopteris bulbifera, Stylophorum diphyllum, Dentaria diphylla, Cardamine douglassii, Viola pubescens, Phlox divaricata, Phacelia bipinnatifida, Erigenia bulbosa, Solidago flexicaulis, Trillium flexipes, Polygonatum pubescens, P. biflorum,* and *Smilacina racemosa.*

Within the *A. saccharum* forest on steeper slopes, the following five intergrading types may be recognized though they are often weakly defined.

1. On seeping slopes and transitions to floodplains, *Hydrangea arborescens* is particularly frequent along with patches of *Hydrophyllum canadense, Impatiens pallida,* and, occasionally, *Laportea canadensis.* More open or disturbed sites often have related species — *Hydrophyllum appendiculatum, Impatiens capensis, Boehmeria cylindrica, Pilea pumila,* and *Urtica chamaedryoides.* Also characteristic are *Athyrium pycnocarpon, Dicentra cucullaria,* and *Valeriana pauciflora.*
2. On steep, rocky sites well above seeps and floodplains, *Hepatica acutiloba* is locally abundant in addition to *Stellaria corei, Erythronium americanum, Sedum ternatum,* and other species noted in the general description (F2).
3. On steep, drier, rocky sites, especially on talus or fissured bedrock, *Quercus* spp., *Fraxinus* spp., and *Staphylea trifolia* are common. The ground layer is often dominated by *Polymnia canadensis*, with frequent *Dryopteris marginalis, Cystopteris protrusa, Hepatica acutiloba,* and *Allium tricoccum. Dentaria laciniata, Cardamine douglassii, Sedum ternatum, Saxifraga virginiensis,* and *Solidago flexicaulis* are occasional. *Erythronium* spp. are virtually absent, and less *Stellaria corei, Asarum canadense, Isopyrum biternatum,* and *Claytonia virginica* are found.
4. On gentler, convex slopes of low ridges, benches, and terraces with less unstable colluvium, occasional patches of *Podophyllum peltatum* occur, often with *Cystopteris protrusa* and *Polemonium reptans.* Other mesic species are similar except for a general absence of *Asarum canadense* and *Allium tricoccum. Fagus grandifolia* and *Liriodendron tulipifera*

may be concentrated on such sites, though these trees are infrequent to rare at Raven Run.

5. On gentler upland slopes generally in the transition to more disturbed forest on the broad ridges, *Carya cordiformis* and *Fraxinus americana* are common to locally abundant, and *Acer nigrum* is more frequent than *A. saccharum. Hydrophyllum macrophyllum* is a common to locally abundant addition to the herbaceous vegetation. Other frequent additions include grasses (especially *Elymus villosus, Bromus pubescens,* and *Poa sylvestris*), sedges (especially *Carex jamesii*), and *Bignonia capreolata.* Less *Stellaria corei* and a general absence of *Asarum canadense* and *Allium tricoccum* were noted.

***Acer nigrum* Forest (and Disturbed Variants) on Gentler Slopes (F2).** On deeper soils of the McAfee series, shade-tolerant *Acer nigrum* may be dominant, at least in the subcanopy. However, *Carya cordiformis* (and an occasional *C. laciniosa*), *Celtis occidentalis,* and *Juglans nigra* are frequently intermixed and probably increased due to past disturbance. Other trees include *Quercus muehlenbergii, Fraxinus americana* (and an occasional *F. quadrangulata*), *Ulmus rubra, U. americana, Aesculus glabra,* and *Gymnocladus dioica. Lindera benzoin* is frequent in less disturbed areas, and *Symphoricarpos orbiculatus* occurs in more disturbed areas. Herbaceous vegetation is highly variable, perhaps due to grazing in the past. Abundant species in less disturbed areas consist of *Stellaria corei* and *Hydrophyllum macrophyllum.* Abundant in some areas are *H. appendiculatum,* a biennial, and *Collinsia verna,* one of the few winter annuals in the mature mesic forests of eastern North America (Baskin and Baskin, 1983). In the early 1970s, *C. verna* was largely restricted to the Collinsia Creek watershed, but this species appears to have spread greatly since then. Also frequent are *Isopyrum biternatum, Delphinium tricorne, Sanguinaria canadensis, Polemonium reptans, Polygonatum biflorum, Trillium sessile,* and *Erythronium americanum.* Occasional species include *Cystopteris protrusa, Viola pubescens, V. sororia, V. striata, Tradescantia subaspera,* grasses (especially *Festuca subverticillata* and *Elymus villosus*), and sedges (especially *Carex albursina, C. laxiflora, C. blanda, C. jamesii,* and *C. oligocarpa*). Grasses and sedges are more common in disturbed areas, as are the additional annual species *Phacelia purshii, Chaerophyllum procumbens, Galium aparine,* and *Stellaria media.*

STREAMSIDE FOREST

Restricted to narrow alluvial strips on the Huntingdon soil series and its rocky variants, this community (G in Figure 2 and Table 1) includes frequent *Platanus occidentalis, Acer negundo, Lindera benzoin, Impatiens* spp., *Laportea canadensis, Boehmeria cylindrica, Pilea pumila, Polygonum* spp., and *Cryptotaenia canadensis,* usually mixed with species typical of adjacent slopes. A few creek bottoms near the river are 15-30 m wide and have many species in common with the forest on deeper upland soils. On the Kentucky River bank, *Acer saccharinum* replaces *A. negundo* among more abundant species, and less admixture of upland species occurs.

NOTES ON RARE PLANT SPECIES

Twenty-three of the species found at Raven run are rare in the Bluegrass Region, with only 1-10 records in most cases. The 10 species with "R" in parentheses after their names are rare in Kentucky as a whole (Warren, *et al.,* 1986; U.S. Department of the Interior, Fish and Wildlife Service, 1990). The additional 13 species are rare in the Bluegrass but are more frequent elsewhere in Kentucky. Some excluded species of marginal rarity still have biogeographic interest since they are restricted to the Palisades and other rocky areas near the Kentucky River in central Kentucky. These species include widespread Appalachian species at the edge of their range, such as *Aesculus flava, Poa cuspidata,* and *Silene rotundifolia,* as well as species of calcareous regions, such as *Ulmus thomasii, Ribes missouriense, Lonicera dioica,* and *Draba ramosissima* (Campbell and Meijer, 1989).

***Allium burdickii* (R).** Until Jones (1979) recognized *A. burdickii* as a species, this taxon was neglected or called a variety of the more common *A. tricoccum. Allium burdickii* has: 1) smaller overall size, with leaves averaging 2-4 cm wide versus 5-8 cm in *A. tricoccum*; 2) pedicels more erect (at about 30°-60° to the scape versus 60°-120°) and fewer (10-20 versus 30-50) in a smaller umbel; 3) earlier flowering, in late May-June when some old leaves are still present (*A. tricoccum* flowers in late June-July after the leaves have died down); and 4) a lack of anthocyanic pigmentation. Both taxa have north-central to Midwestern ranges, but *A. burdickii* is concentrated in the Midwest and in drier forest with *Quercus* in addition to *Acer saccharum.* In Kentucky, *A. burdickii* is known from at least 15 sites in seven north-central counties, all on limestone substrates. The two Raven Run sites are on moderately steep, mid-to-upper, north-facing slopes in *A. saccharum* forest with a *Quercus-Fraxinus* component, and above small cliffs south of the North Fork mouth of Raven Run Creek (near *Pachysandra procumbens,* see below). *Allium tricoccum* is much more abundant at Raven Run but occurs mostly on moister, lower slopes along larger creeks.

Aplectrum hyemale. This north-central species is infrequent on fairly moist, fertile soils in forested areas surrounding the Bluegrass. The only Bluegrass records are from Fayette (a 1990 collection, 2 km to the south, along Dry Branch) and Madison (1 mile north of Hines Creek) Counties. The single Raven Run plant was in young *Juniperus* woods on the upper, west-facing slope about 120 m northwest of the amphitheater.

Aureolaria flava. This north-central species is virtually unknown in the Bluegrass, though frequent on limestone in the surrounding Knobs Region and Mississippian Plateaus. In 1989, *A. flava* was found on dry slopes north of the mouth of Raven Run Creek.

Carex laxiculmis. This north-central species is frequent on moist, non-calcareous soils along small streams in regions surrounding the Bluegrass. The only Bluegrass collection is from the banks of Chandler Creek at Raven Run.

Carex plantaginea. The only certain Bluegrass record of this northern and Appalachian species is from Raven Run. Some 50-100 plants occur in two patches around low seeps and gullies on the cool northeast-facing slope between the Forks and Collinsia Creek in a forest with much *Acer saccharum* and *Allium tricoccum.*

Chimaphila maculata. This Appalachian species is frequent in woods on moist to dry, acid soil in Kentucky. The only Bluegrass records are from Jessamine (in cedars near the YMCA camp), Garrard (west of the US 27 bridge), and Fayette (H. Clay High School; Dry Branch; and Raven Run) Counties. At Raven Run, a few plants were found during the 1970s near the Red Trail above the South Fork in mixed *Quercus-Acer* forest. In 1989, only one plant could be found 1-2 m below a trampled area.

Goodyera pubescens. This eastern orchid is widespread in woods on dry to moist, acid soil in Kentucky. The only Bluegrass localities known to us are at Raven Run, Jessamine Gorge, and the Crawfort Farm in Anderson County. At Raven Run, plants have been seen along trails in mixed *Quercus-Fraxinus* and *Acer* forest near the Forks and at two places along Chandler Creek. No plants were found in 1989.

***Juglans cinerea* (R).** This north-central species has declined throughout much of its range during the past 100 years, apparently because of disease. Currently, *J. cinerea* is a candidate for federal protection. The species was formerly frequent in successional woods on moist soils of moderate fertility in Kentucky, but *J. cinerea* has now virtually disappeared from parts of the Bluegrass Region. At Raven Run, a few small trees had been seen since 1975 near the overlook and on the west-facing slope along the South Fork. However, these trees are now dead. A larger tree (ca. 40-50 cm dbh) was found in the 1970s along the North Fork below the solar house.

Lilium michiganense. This Midwestern species occurs infrequently in west-central Kentucky. The only Bluegrass records are from Jessamine and Fayette Counties. At Raven Run, a few plants were found in the 1970s and 1980s along the North Fork, just north of the Forks. The plants have not been relocated in recent years.

***Malvastrum hispidum* (R).** This largely Midwestern species is typical of rocky prairies and barrens and was recently made a candidate for federal protection (U.S. Department of the Interior, Fish and Wildlife Service, 1990). Kentucky records are primarily from the Inner Bluegrass. The only post-1960 Bluegrass collections known to the authors are from Raven Run in open areas with some *Juniperus,* probably near the upper trail northwest of the barn, and from Madison County opposite Clay's Ferry.

Monotropa uniflora. This non-photosynthetic species is widespread in woods on acid soils throughout most of Kentucky and much of North America. The only records from the Bluegrass Region are collections from Campbell and Grant Counties along with an observation at Raven Run. One clump of this species was seen along the main trail to the river overlook (south of the mouth of Collinsia Creek) in 1989. The forest is dominated by *Quercus-Fraxinus* and *Acer* with frequent *Carya ovata. Orobanche uniflora,* also rare within the Bluegrass Region, was observed earlier in the 1980s on this same trail closer to the overlook and on the southwest face along Raven Run Creek.

***Onosmodium hispidissimum* (R).** This largely Midwestern species has been listed as "endangered" in Kentucky (Warren, *et al.,* 1986). Five records are known from the Bluegrass Region. The population at Raven Run, discovered in 1987 (M. Bender, pers. comm.), is south of the field with powerlines near an old fencerow of *Juniperus virginiana, Prunus serotina, Ulmus americana, Quercus* *muehlenbergii,* and *Vitis vulpina.* About 15 plants are scattered along 10 m of an old road bed (1-3 m southeast of the fencerow) in thin vegetation on rather dry ground that has been compacted and eroded. The dominant species is *Trifolium campestre*; others include *Poa pratensis* (ssp. *angustifolia*?), *Monarda fistulosa, Solidago altissima, Achillea millefolium, Melilotus officinalis, Chrysanthemum leucanthemum, Ipomoea pandurata, Dianthus armeria, Desmodium perplexum, Fragaria virginiana, Symphoricarpos orbiculatus,* and *Rhus aromatica.* A second patch of about 12 plants occurs in similar vegetation about 120 m to the west.

Pachysandra procumbens. This southeastern species, common in woods on moist, fertile soil (especially on limestone), reaches its northern limit on a line running from southern Indiana (Harrison County) to central Kentucky (Fayette County). Four sites are known in the southern Bluegrass and Knobs Regions (including Jefferson, Jessamine, and Garrard Counties). At Raven Run, *P. procumbens* occurs on lower north-facing slopes above the old mill site. The species is reported to sometimes escape from cultivation (Fernald, 1950). However, the plants here occur in a mature *Acer saccharum* forest with virtually no exotics. Several patches, totaling at least 100 m^2, are scattered within a zone 30 m wide and 150 m along the slope. Although some plants near the trail above the old mill were trampled out since 1980, the whole population appears larger than 10-15 years ago. Several patches of *Allium burdickii* occur near *P. procumbens.*

Panax quinquefolium. This north-central species was once widespread in woods on moist, moderately fertile soils in Kentucky before harvesting greatly reduced the population. Only three Fayette County reports are known from the past 20 years — at Henry Clay High School, Boone Creek, and Raven Run, where a plant was found in 1983 just south of the mouth of Chandler Creek.

Panicum anceps. This south-central species is widespread in fields having acid soils in Kentucky. The three Bluegrass records are from Fayette, Madison, and Shelby Counties. At Raven Run, two 1-3 m^2 patches were found along mowed paths across the central field.

***Prenanthes crepidinea* (R).** This species appears to be rare throughout its Midwestern range and deserves study for federal listing. In Kentucky, recent records occur from only five counties: Rockcastle, Estill, and Leslie (Campbell, *et al.,* 1993) as well as Graves and Fayette. C.W. Short and R. Peter collected *P. crepidinea* during the 1830s in thickets near Lexington. The species was rediscovered in 1979 at Raven Run, and 100-200 plants occur on south-to east-facing wooded slopes just above the steepest rocky section of Collinsia Creek. The mixed hardwood forest with *Acer nigrum* dominant is relatively mesic but with a few subxeric species present. A feature of this population in recent years is that all leaves and stems die down in July without flowering. However, flowering was observed in 1979. Roots transplanted in 1989 from Raven Run to rich garden soil in full sun produced 1½-2 m tall flowering stems and abundant seed in August-October of 1991.

***Prunus virginiana* (R).** In Kentucky, this widespread northern species is near its southern limit, and only about 10 localities are known, mostly along the Palisades. In Fayette County, R. Peter collected *P. virginiana* in 1834 on the banks of North Elkhorn Creek near Paris Pike (MacFarlane, 1979), but the only currently known locality is Raven Run. Ten patches were found on the crest of northwest- to northeast-facing cliffs along Raven Run Creek and its South Fork, and one patch was found on the dry, east-facing clifftop north of the mouth of Raven Run Creek. Each patch contains 10s to 100s of stems, covers 10-100 m^2, and may be a single clone connected by roots. The forest is generally dominated by *Acer nigrum* or *A. saccharum* with *Fraxinus quadrangulata* and *Quercus muehlenbergii* on the drier sites. The ground vegetation is mostly typical for *A. saccharum* forest with abundant *Hepatica acutiloba* and *Podophyllum peltatum.*

Solidago harrisii **(R).** This broad-leaved goldenrod occurs in open rocky woods on limestone or shale and is best known from the shale-barrens region in the Ridge and Valley Province. *Solidago harrisii* was recently discovered in Kentucky (Estill, Powell, Rowan, and Morgan Counties) on limestone at the edge of the Appalachian Plateau (Campbell, *et al.,* 1989, 1993). At Raven Run, several plants were found on the upper slopes of the southeast-facing point just north of the mouth of Raven Run Creek.

Solidago rupestris **(R).** This east-central species, largely restricted to riverbanks with exposed limestone, is locally frequent along the Kentucky River in the Bluegrass Region. Just north of the mouth of Raven Run Creek, several plants were found on rocky banks in brushy to grassy vegetation.

Spiranthes ovalis. This orchid occurs widely in woodland on moist, fertile soil in the south-central States but has been found in only 10 Kentucky counties. Two known Bluegrass localities are at Jessamine Gorge and Raven Run, where about seven plants were found along the trail 300 m west of the river overlook in the early 1980s. In 1989, *S. ovalis* could not be found there, but one plant was found on the trail from the barn to Chandler Creek. Both sites were in relatively young *Juniperus* or *Juglans-Celtis* forest, and the plants occurred 0.2-2 m from the trail. Like some other orchids, this species may be favored by disturbance along the trail-side vegetation.

Synandra hispidula **(R).** This east-central species has recently been dropped as a candidate for federal protection. Kentucky is at the center of its range, and a cluster of records is known from ravines along the Kentucky River. One population has been found at Raven Run on a steep north-facing slope along Raven Run Creek. About 50 flowering plants were seen in 1989. This species is biennial, and whole populations tend to flower in alternate years (Baskin, *et al.,* 1986). The forest at this site is relatively mature, dominated by *Acer nigrum,* but includes *Aesculus glabra, A. flava, Juglans nigra, Quercus shumardii, Q. rubra,* and *Lindera benzoin. Carex plantaginea* (discussed above) occurs on slopes directly below the *Synandra.*

Tipularia discolor. This south-central species is widespread on moderately dry, acid soil in Kentucky forests. The few Bluegrass records are all from the Palisades section, in Jessamine (Jessamine Gorge, Indian Falls), Madison (Hines Creek) (Martin, *et al.,* 1979), and Fayette Counties (Raven Run). At Raven Run, scattered plants (ca. 10-20 during the 1980s) have been observed along several trails on the upper north-facing slopes; i.e., 30-300 m west of the river overlook, along the mid-slope trail 100 m south of the forks (Old Mill), and in a young forest northwest of the barn.

Viburnum molle **(R).** This Midwestern species has been reported from about 10 Kentucky counties, mostly in limestone ravines along the Kentucky River within the Inner Bluegrass Region. Population density is generally low. At Raven Run, only one plant was found on the crest of a small, low, northeast-facing cliff along Raven Run Creek.

DISCUSSION

Floristic Comparison with Other Palisades' Areas. Raven Run is in the outlying eastern section of the Kentucky River Palisades between Valley View and Boonesboro. This section is in the strictly defined Inner Bluegrass on Lexington Limestone and High Bridge rocks. Both up- and downstream, the bedrock is primarily the Clay's Ferry Formation of the Eden Shale Belt and is without cliffs. The only other Palisades ravine, whose vascular flora has been extensively surveyed, is Jessamine Gorge (Campbell and Meijer, 1989), which lies in the central Palisades with particularly high cliffs of the High Bridge Group.

Of the 541 vascular plant species found at Raven Run (including adjacent ravine slopes), over 90% were also found at Jessamine Gorge (Campbell and Meijer, 1989). Despite the similarity in the flora of the central and eastern Palisades, many of the rarer species reported from the central Palisades, especially those of extreme or unusual habitats, are unknown at Raven Run, including *Cerastium arvense* L., *Cladrastis lutea* (Michx. f.) Koch, *Hypericum sphaerocarpum* Michx., *Melica nitens* Nutt., *Oryzopsis racemosa* (Smith) Ricker, *Paxistima canbyi* Gray, *Phlox bifida* Beck, *Schizachne purpurascens* (Torr.) Swallen, *Trillium nivale* Riddell, *Waldsteinia fragarioides* (Michx.) Tratt., and *Viola walteri* House. Of these, only *O. racemosa, S. purpurascens,* and *V. walteri* have been reported in the eastern Palisades at Boone Creek. Also virtually unknown in the eastern Palisades are some species of the central Palisades which occur on low terraces (e.g., *Iris cristata* Ait., *Meehania cordata* (Nutt.) Britton, and *Monarda clinopodia* L.) and on high terraces, ridges, and blufftops (e.g., *Aster macrophyllus* L., *Hydrastis canadensis* L., *Pedicularis canadensis* L., *Perideridia americana* (Nutt.) Reichb., *Quercus falcata* Michx., and *Veronicastrum virginicum* (L.) Farw.). Among rare species more widely scattered in the Palisades, *Sagina fontinalis* Short & Peter is notably absent at Raven Run, though suitable habitat exists on some mossy seeps.

In contrast, several species from the Raven Run area are essentially unknown in the central Palisades. Some are rare in the Bluegrass but frequent in Appalachian Kentucky or other regions with more acid soils (e.g., *Aplectrum hyemale, Carex laxiculmis, C. plantaginea, Chimaphila maculata,* and *Panicum anceps).* In addition, two species at Raven Run, *Aureolaria flava* and *Solidago harrisii,* are typical of dry calcareous woods in the Eastern Knobs. The presence of these species in the more eastern Palisades area might reflect shorter dispersal distances from Appalachian regions. *Malvastrum hispidum, Onosmodium hispidissimum,* and *Prenanthes crepidinea,* which occur on upper slopes and ridges at Raven Run but are unknown in the central Palisades, may be relics of open woods, grasslands, or glades on uplands' Lexington Limestone.

Comparison of Forest Vegetation. Shifts in dominant species and average forest composition along the Palisades are probably minor (Martin, *et al.,* 1979; Campbell and Meijer, 1989). However, because of its more rugged and varied topography, Jessamine Gorge has more unusual or extreme soils. Forest types that are better developed there include: *Fagus-Liriodendron* on acid terraces and benches; *Quercus alba-Carya ovata* on infertile ridges and blufftops; and brushy open *Quercus muehlenbergii-Fraxinus quadrangulata-Juniperus* on xeric, narrow, dolomitic points. Compared to Jessamine Gorge, Raven Run has a larger proportion of forest on deeper soils, because the Sanctuary extends further up onto broader ridges. Although generally no more than 50 years old, the ridge forest at Raven Run will ultimately provide an opportunity to compare the undisturbed vegetation on deep soils of the Inner Bluegrass plains (Maury and McAfee series) with that on shallow soils of the Palisades (Fairmount and shallower McAfee). This edaphic gradient had no clear shift in mesic versus subxeric vegetation before settlement (Campbell, 1980, 1987). On the plains prior to settlement, subxeric forest, dominated by *Quercus, Fraxinus,* and *Carya,* occurred only in the putative fire-maintained, savanna-like woodlands (Bryant, *et al.,* 1980), while in the Palisades, these genera tend to dominate only on south- to west-facing slopes and ridgetops (Martin, *et al.,* 1979).

Of particular interest are the changes that occur among species of mature mesophytic forest from deep residual soils typical of the plains to shallow colluvial soils typical of the ravines. In addition to the current survey, the following comparisons include observations from previous studies (Campbell, 1980, 1989; Campbell and Meijer, 1989). On deeper soils, abundant trees include *Acer nigrum* (locally dominant), *Carya cordiformis* (often codominant), *Celtis occidentalis, Ulmus americana, Juglans nigra, Aesculus glabra, Gymnocladus dioica,* and *Quercus macrocarpa* (rare at Raven Run). Abundant trees on shallower soils include *Acer saccharum* (dominant), *Quercus rubra* (often codominant), *Q. muehlenbergii, Aesculus flava, Tilia* spp., and *Ulmus rubra.* More widely distributed trees include *Q. shumardii* and *Fraxinus americana.* Abundant forest herbs with peak abundance on deeper soils include *Cystopteris protrusa, Viola papilionacea, V. striata, Osmorhiza longistylis, Chaerophyllum procumbens, Phacelia purshii, Hydrophyllum macrophyllum, Polymnia uvedalia, Eupatorium rugosum, Polygonatum canaliculatum, Camassia scilloides, Festuca subverticillata, Poa sylvestris, Elymus* sp. nov. (Brooks), *Carex blanda, C. jamesii,* and *C. oligocarpa.* Those abundant on shallower soils include *Dryopteris marginalis, Cystopteris bulbifera, Asarum canadense, Hepatica acutiloba, Viola sororia, V. pubescens, Osmorhiza claytonii, Phacelia bipinnatifida, Hydrophyllum canadense, Polymnia canadensis, Solidago flexicaulis, Polygonatum pubescens, Allium tricoccum, Elymus villosus, Carex careyana, C. albursina, C. laxiflora,* and *C. communis.* Widespread species in both forest types include *Stellaria corei, Erythronium americanum,* and *Polygonatum biflorum.* A similar edaphic gradient may be evident in early forest succession. Whether this vegetational gradient from steep to gentle slopes is due to direct edaphic factors, or whether there are complicating indirect relationships with microclimate (e.g., more humidity in the ravines), hydrology (e.g., more seeps in the ravines), herbivores (e.g., more grazing, trails, and burrows on deeper soils), or other disturbances (e.g., more tree falls in the ravines) needs further research.

While this gradient includes several intrageneric species shifts, few clear shifts occur among higher taxa or life-forms. However, most spring-flowering winter annuals in Bluegrass woodlands are typical of deeper mesic soils (i.e., *Stellaria media, Lamium purpureum, Galium aparine, Urtica chamaedryoides, Corydalis flavula, Phacelia purshii, Chaerophyllum* spp., *Collinsia verna,* and *Valerianella* spp.). Only a few of these species extend to shallower soils, sometimes mixing with the few winter annuals of rocky openings (e.g., *Sedum pulchellum* and *Arenaria patula*) and summer annuals of disturbed areas (e.g., *Parietaria pensylvanica, Cuphea viscosissima,* and *Torilis arvensis*). In contrast, most biennials (e.g., *Phacelia bipinnatifida, Hydrophyllum appendiculatum,* and *Synandra hispidula*) and monocarpic species of more variable age (e.g., *Campanula americana, Polymnia canadensis, Arabis laevigata,* and *Frasera caroliniensis*) are most frequent on shallower mesic to subxeric soils, and some mix with the summer/fall annuals of seeps and floodplains (e.g., *Pilea pumila, Impatiens* spp., *Polygonum* spp., and *Microstegium vimineum*). The exotic biennial, *Alliaria petiolata,* is exceptional, occurring widely on deeper upland soils. Although several monocarpic woodland species have been studied (Baskin and Baskin, 1975, 1979a, 1984; Bender, 1991; Bloom, 1988), why most of them are more frequent on the calcareous soils of central Kentucky, rather then on acid Appalachian soils, is not known. Favorable factors for success in deciduous forests on fertile calcareous soils might be greater light and/or nutrient levels during the winter as well as the fluctuating impacts of herbivores. Longer-lived monocarpic species may respond greatly to variation in water supply from year to year (Bender, 1991; Bloom, 1988).

Old-Field Succession. Old-field succession in east-central States includes the following general features (Bard, 1952; Bazzaz, 1968, 1975; Drew, 1942; Inouye, *et al.,* 1987; Keever, 1950, 1979, 1983; Odum, 1960; Oosting, 1942; Pickett, 1982; Quarterman, 1957; Thomson, 1943; Tilman, 1987).

1. During the first 1-5 years, annuals are frequent. These annuals include a few native Asteraceae (i.e., *Ambrosia* spp., *Bidens* spp., and *Erigeron* spp.); several Poaceae, mostly warm-season and exotic (i.e., *Panicum* spp., *Aristida* spp., *Setaria* spp., *Digitaria* spp., *Cynodon dactylon* (L.) Pers., and *Bromus* spp.); Brassicaceae, mostly exotic (i.e., *Barbarea* spp., *Brassica* spp., *Cardamine* spp., *Draba* spp., and *Lepidium* spp.); Caryophyllaceae, mostly exotic (i.e., *Stellaria* spp., *Cerastium* spp., and *Holosteum umbellatum*); a few exotic Fabaceae (i.e., *Melilotus* spp. and *Lespedeza* spp.); and others (i.e., *Oxalis* spp., *Ipomoea* spp., *Lamium* spp., *Plantago* spp., *Diodia* spp., *Mollugo verticillata, Amaranthus* spp., and *Chenopodium* spp.).
2. During the years 2-10, monocarpic species and competitively inferior biennials and perennials reach their greatest abundance. Included in this group are several Asteraceae (i.e., *Cirsium* spp., *Carduus* spp., *Chrysanthemum* spp., *Gnaphalium* spp., *Hieracium* spp., *Aster pilosus,* and *Solidago nemoralis*) and others (i.e., *Trifolium* spp., *Fragaria* spp., *Potentilla* spp., *Rumex* spp., *Oenothera* spp., and *Daucus carota*).
3. During years 5-20, tall perennials are dominant along with a few exotics. Common species include several Asteraceae (i.e., *Solidago* spp., *Aster* spp., *Vernonia* spp., *Verbesina* spp., *Eupatorium* spp., and *Helianthus* spp.), Poaceae (i.e., *Andropogon* spp., *Sorghastrum* spp., *Sorghum* spp., *Panicum* spp., *Tridens flavus, Agrostis* spp., and *Poa* spp.), and Fabaceae (*Desmodium* spp. and *Lespedeza* spp.). Most woody pioneers have fleshy fruit or small wind-dispersed seeds, and many spread clonally.

The old fields at Raven Run generally conform to this pattern with *Solidago altissima* and other tall Asteraceae dominant in later stages. However, several species typical of old fields on poorer soils are uncommon or absent at Raven Run. These include *Diodia virginiana* L., *Aristida* spp., *Lespedeza* spp., *Sorghastrum nutans, Andropogon* spp. (except *A. virginicus,* which does occur on poor soil at Raven Run), *Sassafras albidum, Diospyros virginiana* L., and *Pinus* spp. Some of these species might be more common at Raven Run if dry, infertile, and eroded fields had not been so extensively reclaimed by young forest of *Juniperus.* These suggested relationships between old-field composition and soil fertility deserve more study on a regional scale. For example, there is much similarity (e.g., in abundance of Ulmaceae) between the Bluegrass Region of Kentucky and the Central Basin of Tennessee, which has similar phosphatic limestone and high soil fertility (Quarterman, 1957).

Some common exotic weeds of the Bluegrass Region are notably absent or infrequent in the Raven Run fields, including some tap-rooted, short-lived, monocarpic perennials (i.e., *Conium maculatum, Pastinaca sativa, Dipsacus fullonum,* and *Carduus nutans*). In contrast, these perennials are locally abundant on nearby roadsides, where they may be favored by more frequent disturbance (McCarty and Scifres, 1969; Baskin and Baskin, 1979b, 1990). The only frequent monocarpic perennials in the fields of Raven Run are *Daucus carota* and *Cirsium discolor.*

Invasive Exotic Species. About 112 of the 541 vascular species at Raven Run are exotic to North America. Most are restricted to fields, where several are abundant (e.g., *Festuca elatior, Poa pratensis, Dactylis glomerata, Phleum pratense, Bromus japonicus,* and *Trifolium campestre*) or frequent (e.g., *Melilotus officinalis, Potentilla recta, Daucus carota, Dianthus armeria, Chrysanthemum leucanthemum,* and *Achillea millefolium*). Much *Poa pratensis* in this region has Old World origins, but the abundant form with narrower leaves found at Raven Run may be the native taxon called *Poa angustifolia* by Fernald (1950).

A few herbaceous exotics occur more frequently in woody communities than in the open fields. These include *Microstegium vimineum, Ornithogalum umbellatum, Lamium purpureum, Glechoma hederacea, Duchesnea indica, Alliaria petiolata,* and *Stellaria media.* These herbaceous exotics are generally restricted to young or disturbed forests, thickets, and trailsides. However, the annual *Microstegium* and biennial *Alliaria* have invaded mature forests in several regions of Kentucky during recent decades, and these species will probably continue to increase in the Inner Bluegrass. *Microstegium* is widely scattered at Raven Run on moist trails and streambanks, especially the South Fork. *Alliaria* is abundant along the Kentucky River downstream from the central Palisades section and in northern Kentucky. Though uncommon at Raven Run, several plants have been seen along stream banks and the new paved trail.

The most abundant exotics in the woods at Raven Run are the following shrubs and vines.

Lonicera maackii. This northeast Asian species has become the major exotic shrub of the Bluegrass Region since 1950 (Luken, 1988). *Lonicera maackii* is widespread at Raven Run in successional forests but much less frequent in older forest, where dense shade is provided by *Acer saccharum, Fraxinus* spp., and other trees.

Lonicera japonica. This Asian vine is abundant in Kentucky. At Raven Run, *L. japonica* is locally dominant in older fields and in the open parts of younger woods. The species is less frequent in forest with a continuous tree canopy.

Euonymus fortunei. This Japanese vine has spread into parts of the Bluegrass since 1950. At least five patches, 5-25 m^2, occur at Raven Run. Although not yet as widespread in this region as *Lonicera* spp., *E. fortunei* appears more shade-tolerant and persistent in older forest.

Hedera helix. This vine from western Europe is not widespread in Kentucky, but it has formed large patches on some rocky slopes, especially with limestone cliffs. At Raven Run, three dense, spreading patches totaling at least 1000 m^2 occur on moist, shady cliffs and lower slopes near the river. Almost all native ground vegetation has been excluded from these patches.

Less frequent woody exotics include the shrubs, *Rosa multiflora, Euonymus alatus,* and *Rhamnus citrifolia* as well as a tree, *Populus alba.* These exotics are mostly restricted to thickets and forest edges. *Populus alba* has formed a sprouting clone at the edge of the northern field, but most of another clone in young forest (northwest of the barn) has died.

The woody exotics at Raven Run are evergreen, except for *Lonicera maackii,* which is leafless for only 4-5 months. In contrast, the calcareous regions of Kentucky have virtually no native evergreen woody plants except for *Juniperus virginiana* and the facultative evergreen, *Bignonia capreolata* (Campbell, 1980, 1987). This poses an interesting biogeographic question: "Is the paucity of native evergreens a historical accident with Old World species filling previously empty ecological niches, or were ecological factors (possibly eutrophic soils, winter browsing, or fire) inimicable to evergreen species before settlement?" Under current conditions, whether these exotics will persist or perhaps increase in number as the forest ages is unknown, but some appear to pose serious, long-term, competitive threats to the native vegetation. To restore stands of native vegetation may require continual eradication of such exotics.

SUMMARY OF THE OVERALL SIGNIFICANCE OF RAVEN RUN AS A NATURAL AREA

The Raven Run Nature Sanctuary is an excellent area for the preservation and restoration of the native vegetation of the Inner Bluegrass and for related educational and research activities for the following reasons:

1. The 375 acre area is owned by the Lexington-Fayette Urban-County Government and managed primarily for natural qualities. Raven Run is the only permanently protected natural area in Fayette County, other than the nearby Elk Lick Falls area.
2. Twenty-three species found at Raven Run are rare in the Bluegrass Region or, in some cases, throughout Kentucky. These species provide subjects for research on habitat specializations and population dynamics.
3. A diversity of forest types is represented from floodplains, to moist and dry slopes, to broad ridges. Much of the area has been logged, grazed, or farmed in the past, but some of the steeper slopes are dominated by species typical of the inferred climax condition.

4. The ridges have some unusually mature old fields dominated by native herbs, though pasture grasses and exotics are frequent. Two important ecological questions concerning these old fields are (1) whether they are similar to areas disturbed by ungulates and humans before settlement and (2) whether management tools, such as fire, can reduce the proportion of exotic to native species.

ACKNOWLEDGMENTS

The authors wish to express their appreciation to Mary Wharton, Edward Browne, Charles Andre, John MacGregor, and Ellen Dean for the information concerning the vegetation of Raven Run they amassed over the years. This information was inestimable and served as the core of our study. The authors also recognize the invaluable role of TMHG, which was started in 1977 by the late Carl Clark, and are grateful to Tom Barnes, Carol and Jerry Baskin, Marty Bender, Carol Chambers, Cliff Jaggie, Mike Lorton, Bob Muller, and Clara Wieland for their assistance. The research was funded by the Friends of Raven Run, Inc., in consultation with the Raven Run Advisory Board and the Department of Parks and Recreation. The authors also wish to thank Kem Badger and J. Hill Hamon for their critical review of the manuscript and Kem Badger for his technical assistance in the preparation of the vegetation map.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 185-192

MODIFIED ELECTRODES FOR ELECTROCATALYSIS

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ABSTRACT: Glassy carbon electrode (GCE) surfaces were modified by polymeric ruthenium(II) (vinyl) bipyridine[Poly-Ru $(vbpy)_3^{2+}$] films containing the polyoxometalate ions $PMo_{12}O_{40}^{3-}$ (PMo_{12}), $PW_{12}O_{40}^{3-}$ (PW_{12}), and $SiW_{12}O_{40}^{4-}$ (SiW_{12}). The modifications were carried out by reductive electropolymerization of $Ru(vbpy)_3^{2+}$ followed by incorporation of the polyoxometalate anions using an ion exchange method. The modified electrodes were used to catalyze the electroreduction of protons and small oxoanions such as ClO_3^-, BrO_3^-, IO_3^-, and NO_3^-. Electrodes modified with immobilized PW_{12} and SiW_{12} were found to be more effective catalytic reductants than those modified with immobilized PMo_{12}. The catalytic activities of these immobilized polyoxometalates are explained on the basis of their electrochemical behavior in both the free and immobilized states.

KEYWORDS: Electrocatalysis, modified electrodes, oxoanions, and polyoxometalates.

INTRODUCTION

Performing electrochemical reactions at electrode surfaces requires the careful control of the reactivity at the electrode/electrolyte interface. Such control, when it is possible, affects the use of electrochemistry in such areas as analysis, catalysis, and synthesis. By modifying the electrode's surface, a researcher can dictate and control its properties to serve the purpose of a chemical process. In the designed modification process, some of the physicochemical properties of the modifiers are transferred to the electrode's surface, where they enhance such properties as its reactivity, sensitivity, and selectivity.

Because of their chemical stability and their capacity to undergo multi-electron charge transfer reactions, polyoxometalates should be excellent electrocatalysts. A number of reports have discussed the electrocatalytic properties of polyoxometalates and related metal oxide aggregates (Unoura, *et al.*, 1984; Toth, 1990; Toth, *et al.*, 1989; Keita and Nadjo, 1985, 1988a; Kulesza and Faulkner, 1988; Eberson, 1983; Amadelli, *et al.*, 1990; Navalikhina, *et al.*, 1990). When these electrochemical properties are transferred to a native electrode, its electrochemical properties are enhanced. The transfer is achieved by trapping the polyoxometalate anions in chemically modified layers on the electrode's surface (Murray, 1984). Although widely used in applications based on its electron transfer properties, poly-$Ru(vbpy)_3^{2+}$ (Braddock and Meyer, 1973) is also a potentially useful ion

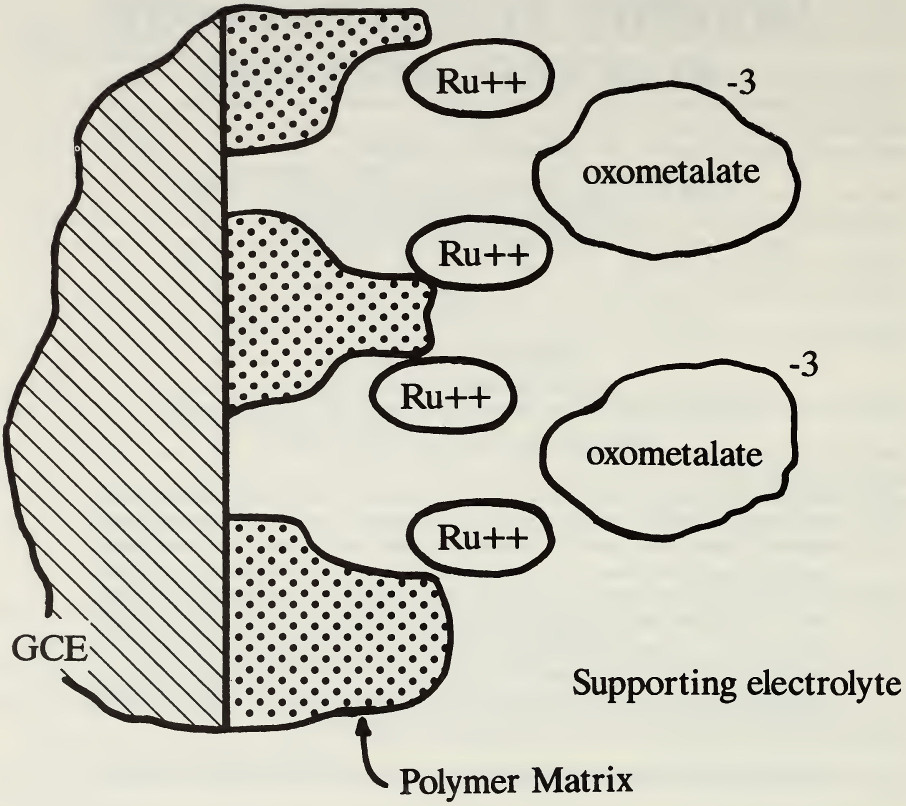

Figure 1. Schematic diagram of a poly-Ru(vbpy)$_3^{2+}$ film containing oxometalate anions on the GCE.

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exchange polymer because of its chemical stability, its wide electrochemical window, and its ability to be used in both aqueous and non-aqueous environments.

The electrochemical behavior of immobilized PMo_{12}, PW_{12}, or SiW_{12} in poly-Ru(vbpy)$_3^{2+}$ has already been studied (Kasem and Schultz, 1995). The present work focuses on the use of electrodes modified with polyoxometalates entrapped in poly-Ru(vbpy)$_3^{2+}$ for the electrocatalytic reduction of H^+ as well as for the electrochemical reduction of some small oxoanions such as ClO_3^-, BrO_3^-, IO_3^-, and NO_3^-.

MATERIALS AND METHODS

The PMo_{12}, PW_{12}, and SiW_{12} heteropolyanions were purchased as phosphomolybdic (Aldrich), phosphotungstic (Fluka), and tungstosilicic (Fluka) acid and used as received. The monomeric reagent, Ru(vbpy)$_3^{2+}$, was prepared from $RuCl_3$ and 4-vinyl-4′-methyl-2,2′-bipyridine (vbpy) (see Braddock and Meyer, 1973) and isolated as the hexafluorophosphate salt. The vbpy ligand was prepared using the procedure discussed by Abruna, *et al.* (1985) and was characterized by 1H NMR spectroscopy. Poly(4-vinyl) pyridine (PVP) was purchased from Scientific Polymer Products. Films of poly-Ru(vbpy)$_3^{2+}$ on GCE

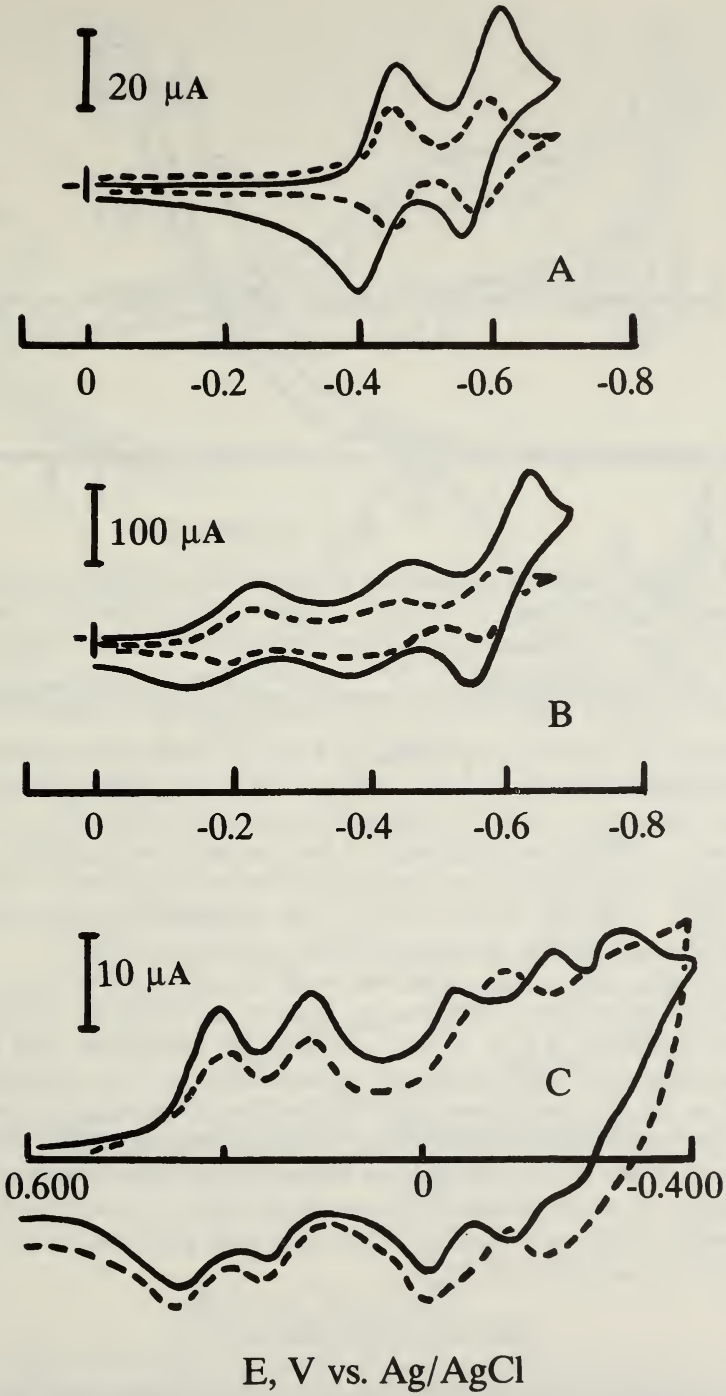

Figure 2. Cyclic voltammograms of 1 mM freely diffusing (——) and immobilized (- - -) oxometalates in poly-Ru(vbpy)$_3^{2+}$ in 50% dioxane/water containing 0.5 M H_2SO_4: A) SiW_{12}; B) PW_{12}; and C) PMo_{12}. The scan rate was 100 mV/sec.

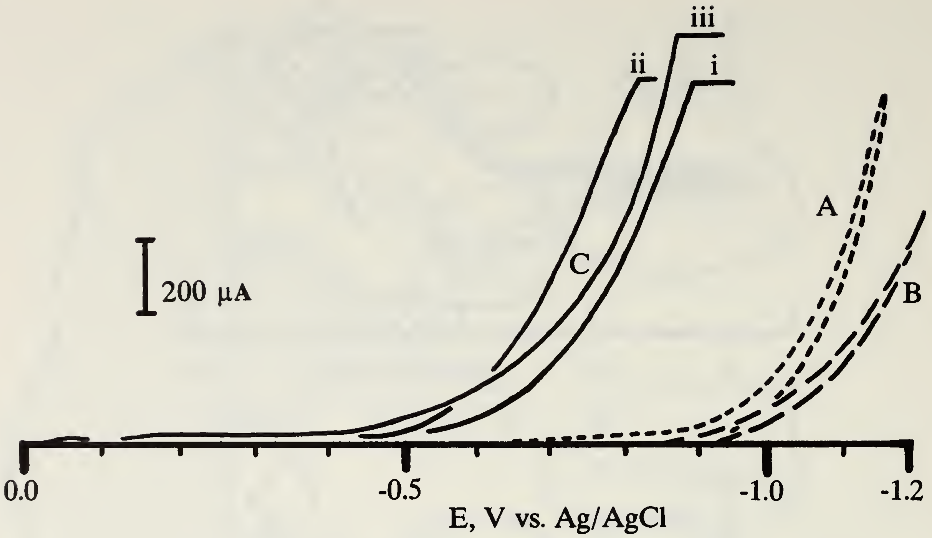

Figure 3. Electrochemical behavior of a bare GCE (A), a GCE modified with multilayers of poly-Ru(vbpy)$_3^{2+}$ films (B), and a GCE modified with multilayers of poly-Ru(vbpy)$_3^{2+}$ films (C) containing PMo$_{12}$ (i), PW$_{12}$ (ii), and SiW$_{12}$ (iii). The scan rate was 100 mV/sec.

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were prepared by cycling the potential of a glassy carbon disk electrode (0.071 cm^2, Bioanalytical Systems) between -0.9 and -1.9 V vs. Ag/AgCl in an acetonitrile solution containing 1-2 mM Ru(vbpy)$_3$(PF$_6$)$_2$ plus 0.1 M Bu$_4$NPF$_6$. Scans were carried out at a sweep rate of 200 mV s^{-1} for a period of ca. 8 minutes, resulting in electrodes whose surfaces were covered by between 4 x 10^{-9} and 9 x 10^{-9} moles Ru per cm^2. Films of PVP on GCE were prepared and cross-linked with 1,12-dibromododecane as described by Keita and Nadjo (1988c).

Heteropolyanions were incorporated in the ion polymer films by soaking the modified electrodes for 2-24 hours in aqueous or 50% (v/v) dioxane/water solutions containing 0.5 M H_2SO_4 and 0.01 M heteropoly acid (Figure 1 illustrates a modified GCE containing oxometalate ions in a poly-Ru(vbpy)$_3^{2+}$ film). Then, the electrodes were rinsed thoroughly and transferred to reactant-free electrolyte, where their electrochemical response was examined. The surface coverage of anions on the electrode was determined by integrating the area under voltammetric i-E curves (see Braddock and Meyer, 1973). The electrode potentials are reported relative to a Ag/AgCl half-cell whose potential is -45 mV vs. a Saturated Calomel Electrode (SCE)

RESULTS AND DISCUSSION

The electrochemical behaviors of the free and immobilized polyoxometalates under study are recorded in Figure 2. The similarities between the redox behavior of the free and immobilized oxometalates are clearly evident. However, two differences were noted. First, small differences were observed between the behavior of free and immobilized PMo$_{12}$ (Figure 2C), particularly in the third

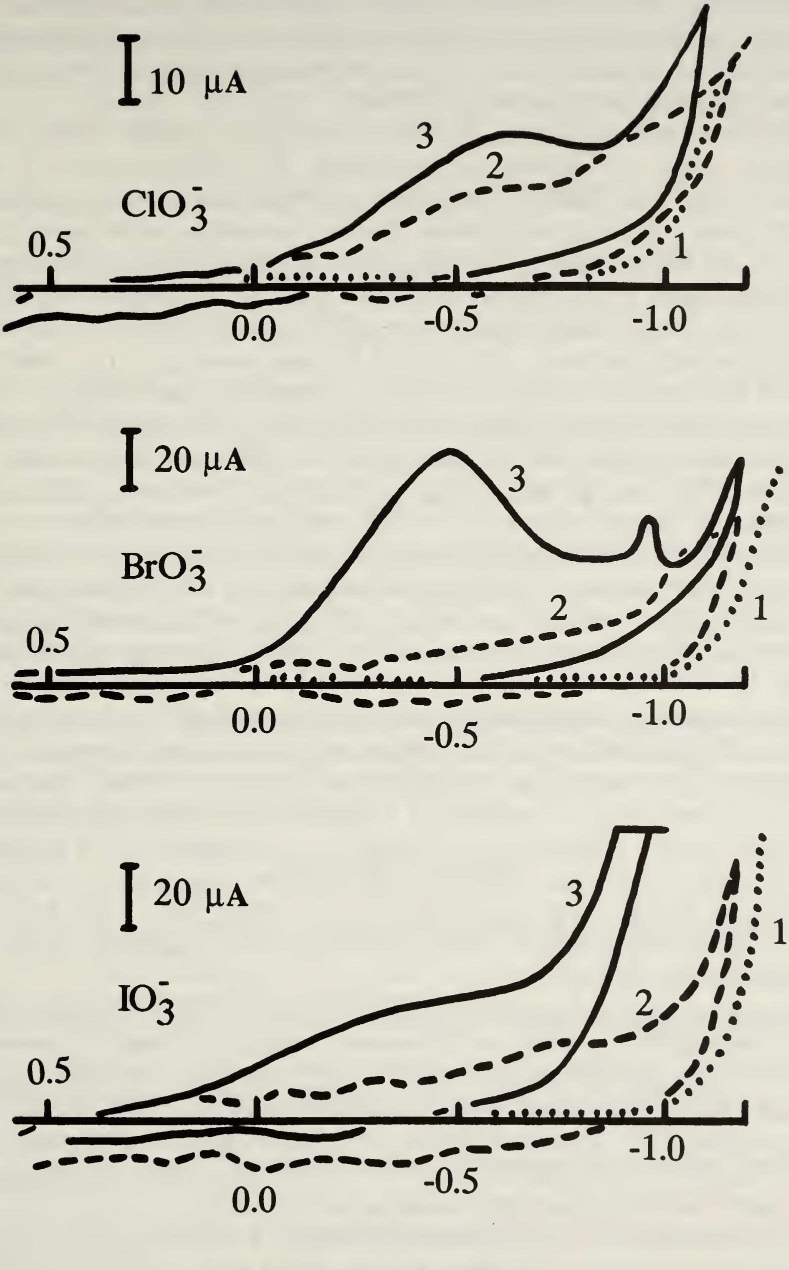

Figure 4. The electrocatalytic reduction of small oxoanions by incorporated PMo_{12}: Trace 1 (···) represents a GCE modified with 6.0×10^{-9} mole/cm^2 poly-Ru(vbpy)$_3^{2+}$ in 1 M KCl + 0.2 M $KClO_3$, $KBrO_3$, or KIO_3; Trace 2 (- - -) represents a GCE modified with 6.0×10^{-9} mole/cm^2 poly-Ru(vbpy)$_3^{2+}$ containing 4.4×10^{-10} mole/cm^2 of PMo_{12} in 1 M KCl; and Trace 3 (—) represents an electrode of trace 2 in 1 M KCl + 0.2 M $KClO_3$, $KBrO_3$, or KIO_3. The sweep rate was 20 mV/sec.

and fourth redox waves, which partially overlapped in the immobilized state. The overlapping was attributed to a change in the Lewis acid base characteristics of the host medium (Kasem, 1994). Second, the redox potentials of PMo_{12} are more positive than those of either PW_{12} or SiW_{12}.

Electrocatalytic Reduction. The electrocatalytic activities of the modified electrodes were investigated by comparing the cathodic scan of native, poly-Ru(vbpy)$_3^{2+}$ modified and poly-Ru(vbpy)$_3^{2+}$/polyoxometalates modified GCE in electrolytes containing the substrate. The electrocatalytic reduction of H^+ in 0.5 M H_2SO_4 by PMo_{12}, SiW_{12}, and PW_{12} ions incorporated in poly-Ru(vbpy)$_3^{2+}$ is illustrated in Figure 3. The overpotential for H^+ reduction is diminished by 0.3-0.5 V relative to its value at bare and poly-Ru(vbpy)$_3^{2+}$-modified GCE. Noticeable H^+ reduction occurred between -0.5 and -0.7 V, corresponding to the addition of a total of 4 electrons to both PW_{12} and SiW_{12} and 8 electrons to PMo_{12}. Although hydrogen evolution has been detected at the potential of the first SiW_{12} reduction wave (Keita and Nadjo, 1987), apparently several electrons must be added to the polyoxometalate lattices before they can catalyze H^+ reduction efficiently as homogeneous reactants. Keita and Nadjo (1985, 1987, 1988b) have observed efficient H_2 formation under less forcing conditions using surfaces modified by electrodeposited derivatives of polyoxometalates, but the composition of these electrodeposited layers has not been established. The results suggest that W-based polyoxometalates are more effective at H^+ reduction than those based on Mo.

Electrocatalytic reduction of some small oxoanions. The electrochemical reduction of mononuclear oxo complexes of molybdenum and tungsten is known to catalyze the reduction of small inorganic anions (Lahr, *et al.*, 1984). The reactions proceed by inner-sphere mechanisms at labile, water-containing coordination sites on the metal. Similar sites are thought to be available on the periphery of reduced polyoxometalates, and these species have been used to catalyze the reduction of several oxoanions (Unoura, *et al.*, 1984; Toth, 1990; Toth, *et al.*, 1989; Kulesza and Faulkner, 1988; Eberson, 1983; Amadelli, *et al.*, 1990; Navalikhina, *et al.*, 1990).

The electrocatalytic reductions of ClO_3^-, BrO_3^-, and IO_3^- at poly-Ru(vbpy)$_3^{2+}$ films containing PMo_{12} anions are illustrated in Figure 4. Catalytic current begins to flow at potentials more negative than ca. -0.1 V for ClO_3^- and BrO_3^- and at ca. 0.15 V for IO_3^-. These values coincide with the addition of either six (ClO_3^- and BrO_3^-) or four (IO_3^-) electrons to PMo_{12}. While six electrons are appropriate for the stoichiometric reductions of ClO_3^- to Cl^- and BrO_3^- to Br^-, four electrons are appropriate for the stoichiometric reduction of IO_3^- to IO^-.

A large increase in current occurred around -0.8 V (Figure 3C). The lack of surface analysis makes it difficult to explain this increase in current. Perhaps, as more than 12 electrons were added to the PMo_{12} ion, disproportionation reactions occurred leading to the cathodic deposition of nonstoichiometric aggregates.

The electrocatalytic reductions of ClO_3^-, BrO_3^-, IO_3^-, NO_3^-, and NO_2^- on modified GCE with poly-Ru(vbpy)$_3^{2+}$ films containing PW_{12} and SiW_{12} anions are similar to those shown in Figure 4. A qualitative comparison of the catalytic activities of each modifier towards oxoanion reduction was made based on the normalized charge under each cathodic wave. In general, the modified electrodes with immobilized PW_{12} or SiW_{12} were more efficient in oxoanion reduction than those modified with immobilized PMo_{12}. The fact that the immobilized polyoxometalate anions become catalytically active after the addition of at least 4 electrons to the metalate network can be understood by considering the following reduction mechanism, which illustrates the electronation reactions (Souchay, *et al.*, 1964):

$$[M12\ VI] + 2e \Longrightarrow [M10\ VI / M2\ V]$$

$$[M10\ VI / M2\ V] + 2e \Longrightarrow [M8\ VI / M4\ V]$$

$$[M8\ VI / M4\ V] + 2e \Longrightarrow [M6\ VI / M6\ V]$$

where M represents either Mo or W (the protonation reactions are not shown).

Reduction from the VI to V oxidation state is accompanied by changes in the M...M distances (Pope, 1983). When the metalate network contains 4 or more M(V), a strain is created within the Keggin structures. Restabilzing these structures under experimental conditions is accomplished by transferring electrons to the substrate and causing the catalytic action. Addition of more electrons to the metalate network increases the M(V) content, which may cause the disproportionation reactions. The existence of multivalent W aggregates in similar compounds, as detected by X-ray photoelectron spectroscopy, is evidence for such disproportionation. Large scale electrolysis and product analysis experiments are needed to determine if each polyoxometalate ion must be charged with a full complement of reducing equivalents before multi-electron catalysis can proceed. Characterization of the mechanisms and products of these reactions will be the subject of future studies.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 193-206

HISTORICAL AND PRESENT DISTRIBUTION OF FISHES IN THE PATOKA RIVER BASIN: PIKE, GIBSON, AND DUBOIS COUNTIES, INDIANA

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ABSTRACT: Fish communities in the Patoka River have been dramatically altered by historical land use practices. Changes have resulted from coal mining and associated acid mine drainage, channelization, siltation, and oil exploration. All these changes have reduced and compromised available habitats. The Patoka River is the most extensively studied river in southwestern Indiana. Extensive surveys beginning in 1890 have documented the presence of 90 species of fish. In addition, these surveys document the change of habitat occupied by the fish community from a silt-free, lowland stream to a highly turbid stream dominated by a tolerant lowland fish community assemblage.

KEYWORDS: Acid mine drainage, distribution, fish community, Indiana, Patoka River watershed.

INTRODUCTION

A rich legacy of information regarding fish distribution has been assembled for the Patoka River, which enables comparisons of fish community composition over time. Jordan (1890) collected from the Patoka River at Patoka (Gibson County); Moenkhaus (1896) collected from two sites near Huntingburg (Dubois

County); and Hubbs and Lagler (1942) and Lagler and Ricker (1942) collected from Foots Pond (Gibson County). Gerking (1945) collected from eight sites, including three sites on the Patoka River mainstem. More recently, Hottell (1978) evaluated 12 mainstem sites on the Patoka River, Houchins Ditch, and 12 tributaries; Stefanavage (1991) collected from 8 mainstem localities. The current study evaluated 13 mainstem and 36 tributary sites and was supplemented by unpublished information from Lawrence M. Page of the Illinois Natural History Survey (11 tributary sites) and the Indiana Department of Transportation (2 mainstem and 13 tributary sites). As a result, information from a total of 15 mainstem and 60 tributary sites on the Patoka River drainage are reported.

The U.S. Fish and Wildlife Service established the Patoka River National Wildlife Refuge in Pike and Gibson Counties in southwestern Indiana on 7 September 1994. The refuge consists of more than 22,000 acres, including 6,800 acres set aside as wildlife management areas. The project encompasses one of the last remaining stretches of bottomland hardwood forest in the Midwest. The objectives for establishing the Patoka River National Wildlife Refuge included the preservation, restoration, and enhancement of bottomland hardwood wetlands, uplands, migratory bird habitat, and threatened or endangered species habitat. The project area provides excellent production habitat for many species of migratory waterfowl, such as the wood duck (*Aix sponsa*), and includes areas used by Indiana bat (*Myotis sodalis*), a federally endangered species. In addition, populations of the copperbelly water snake (*Nerodia erythrogaster neglecta*), which the U.S. Fish and Wildlife Service is currently proposing as threatened pursuant to the Endangered Species Act of 1973, are known to occur within the refuge's boundary.

The purpose of this study was to evaluate the current condition of the aquatic communities and to identify potential point and non-point sources of contamination in the watershed. A second objective was to document the historical and present distribution of fishes in the Patoka River drainage and to evaluate the changes in fish community composition from a historical land use perspective.

Watershed Description. The Patoka River is a tributary of the Wabash River, originating near Danner's Cemetery near the town of Valeene, Orange County, Indiana. The river flows west for 162 miles across two physiographic units, the Crawford Upland and the Wabash Lowland (Schneider, 1966). The basin includes an area of extensive lacustrine deposits and minimal glacial deposits. The Patoka River watershed includes 862 mi^2 (551,680 acres) in 8 counties in southwestern Indiana. At the upper, eastern end of the watershed, the Patoka River flows rapidly through a narrow floodplain of forested uplands and has a gradient of 12 feet per mile (U.S. Fish and Wildlife Service, 1994). Several small farms are scattered throughout the upper watershed. West of Jasper, Indiana, the flow velocity of the Patoka River quickly diminishes as the river's gradient decreases to 1 foot per mile. The predominant land use changes from forested uplands in the headwaters to agriculture in the lowlands downstream. The Wildlife Refuge is located in this slow, meandering, lowland stretch of the river, which includes a wide floodplain, numerous oxbows, and low, rolling uplands. Major tributaries to the Patoka River include the South Fork Patoka River (with a drainage area of 76.3 mi^2) and Flat Creek (with a drainage area of 58.9 mi^2), both of which were channelized in the early part of this century.

A drainage project in the 1920s and the U.S. Army Corps of Engineers' construction of Patoka Lake in the late 1970s both affected current flow in the Patoka River. In the early 1920s, nearly 100,000 acres of forested wetlands were drained in the floodplain of the lower reaches of the river to advance farming (U.S. Fish and Wildlife Service, 1994). The drainage project changed 36 miles of meandering river into an approximately 17-mile long, dredged, channelized ditch. Nearly 19 miles of natural river meanders were isolated from the main channel, creating oxbow ponds. Water exchange within these man-made oxbows is now limited to periods of high water. Heavy sediment loads carried during these high water periods result in increased sediment deposition in the oxbows. Consequently, the hydrology of these ecologically important units is continually being altered.

Water Quality. The Patoka River watershed is affected by acid mine drainage (Corbett, 1969; Renn, 1989). From the 1800s to the early 1900s, almost all the coal produced in Indiana was from underground mines. Then, surface mining steadily increased until it became the only current mining practice (Powell, 1972). From 1941 to 1980, 16% of Pike County's acres were disturbed by surface mining (Renn, 1989). A significant portion of Pike County (62%) was mined prior to Indiana's comprehensive reclamation law of 1968, resulting in 186 acres of refuse piles, 129 acres of slurry ponds, 3,113 acres of land with less than 75% vegetation cover, and 375 acres of surface water impoundments affected by drainage from the coal-mined areas (Allen, *et al.,* 1978).

The detrimental effects of coal production on water quality in the watershed were first documented in the early 1960s by Corbett (1969). Acid mine drainage from underground and surface mining has altered water quality in the Patoka watershed. Corbett (1969) found a range in pH from 2.6 to 5.5, in alkalinity from 0 to 4 mg/L, in acidity from 38 to 554 mg/L, and in sulfate from 138 to 4400 mg/L based on 37 water samples from the South Fork Patoka River at the SR 57 bridge during the period from 9 April 1962 to 8 July 1968. In addition to coal mining, oil-well-waste pollution is a problem. Corbett (1969) found that during low flows, the Patoka River (in the vicinity of Wheeling) had high chloride concentrations. In 1969, chloride concentrations ranged from 3 to 952 ppm with an average of 47 ppm (sample size = 110). The mean chloride concentration in river water in North America is 8 ppm (Livingstone, 1963). In 1989, Renn reported that acid mine drainage continued to impair water quality in the South Fork Patoka River. Surface water screening toxicity test results, invertebrate community assessments, and water quality data show that acid mine drainage still impairs water quality in the watershed (U.S. Fish and Wildlife Service, unpub. data).

MATERIALS AND METHODS

The Patoka River was evaluated using samples from a variety of habitat types ranging from mainstem segments and large tributary branches such as the South Fork Patoka River to numerous tributary segments that are included in the Patoka River Wildlife Refuge. A total of 118 sites (Table 1) were sampled using either a T&J pulsed DC electroshocker capable of a 300 volt output and 8-10 Amps or,

Table 1. List of collecting localities sampled from the Patoka River drainage (CR = County Road; SR = State Road; IDOT = Indiana Department of Transportation; u/s = upstream; d/s = downstream).

Site Number	County	Site	Collector
1	Gibson	Patoka River at Patoka	Jordan, 1890
2	Dubois	Patoka River near Huntingburg	Moenkhaus, 1896
3	Dubois	Short Creek, Huntingburg	Moenkhaus, 1896
4	Gibson	Foots Pond, 1 mile south of Jimtown	Hubbs and Lagler, 1942; Lagler and Ricker, 1942
5	Gibson	Patoka River at Patoka	Gerking, 1945
6	Pike	Patoka River, 1 mile east Winslow	Gerking, 1945
7	Dubois	Hunley Creek, 3 miles north of Huntingburg	Gerking, 1945
8	Dubois	Indian Creek, 2 miles east of Huntingburg	Gerking, 1945
9	Dubois	Hall Creek, 2 miles south of Jasper	Gerking, 1945
10	Dubois	Patoka River, Dubois	Gerking, 1945
11	Crawford	Little Patoka River, 12 miles northwest of English	Gerking, 1945
12	Orange	Patoka River, 10 miles south of Paoli	Gerking, 1945
13	Gibson	Patoka River, immediately u/s mouth	Hottell, 1978
14	Gibson	Patoka River, US 41 bridge	Hottell, 1978
15	Pike	Patoka River, u/s South Fork to SR 57 bridge	Hottell, 1978
16	Pike	Patoka River, 0.5 mile south of Winslow	Hottell, 1978
17	Pike	Patoka River, SR 257 bridge	Hottell, 1978
18	Dubois	Patoka River, 2.5 miles east-northeast of Millersport	Hottell, 1978
19	Dubois	Patoka River, SR 162 bridge, Jasper	Hottell, 1978
20	Dubois	Patoka River, 3.5 miles northeast of Jasper	Hottell, 1978
21	Dubois	Patoka River, 0.5 mile northwest of Dubois	Hottell, 1978
22	Dubois	Patoka River, 2 miles north-northeast of Dubois	Hottell, 1978
23	Dubois	Patoka River, below Patoka Reservoir	Hottell, 1978
24	Gibson	Keg Creek, 1 mile u/s mouth	Hottell, 1978
25	Gibson	South Fork, 1 mile u/s mouth	Hottell, 1978
26	Pike	South Fork, 9.5 miles u/s mouth	Hottell, 1978
27	Pike	Cup Creek, mouth	Hottell, 1978
28	Pike	Cup Creek, 1 mile u/s mouth	Hottell, 1978
29	Pike	Flat Creek, 5 miles u/s mouth	Hottell, 1978
30	Dubois	Hunley Creek, 5 miles u/s mouth	Hottell, 1978
31	Dubois	Straight River, 1 mile u/s mouth	Hottell, 1978
32	Pike	Flat Creek, 7 miles u/s confluence Hall Creek	Hottell, 1978

Site Number	County	Site	Collector
33	Dubois	Hall Creek, 4 miles u/s confluence Flat Creek	Hottell, 1978
34	Dubois	Polson Creek, 0.5 mile u/s mouth	Hottell, 1978
35	Dubois	Davis Creek, mouth	Hottell, 1978
36	Pike	Patoka River, RM 30.5	Stefanavage, 1991
37	Pike	Patoka River, RM 31.5	Stefanavage, 1991
38	Pike	Patoka River, RM 33.5	Stefanavage, 1991
39	Pike	Patoka River, RM 34.7	Stefanavage, 1991
40	Dubois	Patoka River, RM 42.3	Stefanavage, 1991
41	Dubois	Patoka River, RM 43.5	Stefanavage, 1991
42	Dubois	Patoka River, RM 53.7	Stefanavage, 1991
43	Dubois	Patoka River, RM 55.0	Stefanavage, 1991
44	Gibson	Patoka River, CR 850 west of the bridge east of Mount Carmel	Current study, 1992
45	Gibson	Patoka River, CR 50 west of the bridge, Patoka	Current study, 1992
46	Gibson	Patoka River, CR 50 E, 2 miles east of Patoka	Current study, 1992
47	Pike/ Gibson	Patoka River, Mitchell Road, 2 miles southeast of Oatsville	Current study, 1992
48	Pike	Patoka River, 3 miles north of Oakland City	Current study, 1992
49	Pike	Patoka River, SR 61 bridge, Winslow	Current study, 1992
50	Pike	Patoka River, 0.25 mile south of Survant	Current study, 1992
51	Pike	Patoka River, 0.75 mile north of Pikeville	Current study, 1992
52	Dubois	Patoka River, CR 600 W, Department of Natural Resources access site	Current study, 1992
53	Dubois	Patoka River, 2.5 miles south of Jasper	Current study, 1992
54	Dubois	Patoka River, d/s Jasper WWTP Outfall	Current study, 1992
55	Dubois	Patoka River, northwest of Beaver Creek Reservoir	Current study, 1992
56	Gibson	Patoka River, d/s South Fork Patoka River	Current study, 1992
57	Pike	Lick Creek, unnamed Road, 2 miles west of Arthur	Current study, 1992
58	Pike	Unnamed tributary, South Fork Patoka River, CR 900 S	Current study, 1992
59	Gibson	Lost Creek, CR 650 E, 1.75 miles north of Francisco	Current study, 1992
60	Pike	Rock Creek, 1.5 miles east of Pikesville	Current study, 1992
61	Pike	Unnamed tributary, Sugar Ridge Road	Current study, 1992

Site Number	County	Site	Collector
62	Pike	Robinson Creek, CR 125 S, 2.75 miles northwest of Winslow	Current study, 1992
63	Pike	Stone Coe Creek, SR 61, 0.75 mile northwest of Winslow	Current study, 1992
64	Pike	South Fork Patoka River, CR 1200 S	Current study, 1992
65	Pike	South Fork Patoka River, CR 900	Current study, 1992
66	Pike	South Fork Patoka River, Scottsburg Road	Current study, 1992
67	Pike	South Fork Patoka River, u/s Durham Ditch	Current study, 1992
68	Pike	South Fork Patoka River, d/s Durham Ditch	Current study, 1992
69	Gibson	South Fork Patoka River, SR 57, 3 miles north of Oakland	Current study, 1992
70	Pike	Barren ditch, unnamed CR, 2 miles southwest of Winslow	Current study, 1992
71	Pike	Beadens Creek, north of Cup Creek Church Road	Current study, 1992
72	Pike	Big Creek, CR 625 W bridge, 0.75 mile east of Oatsville	Current study, 1992
73	Pike	Bruster Branch, CR 200 S, 1.5 miles east of Winslow	Current study, 1992
74	Pike	Cup Creek, SR 257, 0.3 mile southwest of Pikeville	Current study, 1992
75	Pike	Durham Ditch, 0.25 mile northwest of Scottsburg	Current study, 1992
76	Pike	Flat Creek, Sugar Ridge Road, 1 mile south of Glezon	Current study, 1992
77	Dubois	Flat Creek, CR 50 N, 7.25 miles west of Jasper	Current study, 1992
78	Pike	Flat Creek, Flat Creek Road, 2.6 miles south of Otwell	Current study, 1992
79	Pike	Hog Branch, Sugar Ridge State Park, 0.75 mile southwest of Survant	Current study, 1992
80	Pike	Houchin Ditch, CR 400 E, 3 miles southeast of Coe	Current study, 1992
81	Gibson	Keg Creek, CR 50 N, 3.75 miles west of Oakland City	Current study, 1992
82	Pike	Sugar Creek, CR 150 S bridge, 3 miles west of Winslow	Current study, 1992
83	Gibson	Turkey Creek, CR 1275 E, 0.75 mile east of Oakland City	Current study, 1992
84	Pike	Unnamed tributary, SR 364, 2 miles south of Winslow	Current study, 1992
85	Pike	Unnamed tributary, 0.25 mile north of Enos Lake	Current study, 1992
86	Pike	Unnamed tributary, Sugar Ridge Road	Current study, 1992
87	Pike	Unnamed tributary, Liberty Road bridge	Current study, 1992

Site Number	County	Site	Collector
88	Pike	Wheeler Creek, Kays Road, 1 mile east of Coe	Current study, 1992
89	Gibson	Yellow Creek, CR 400 N	Current study, 1992
90	Pike	Mill Creek, SR 364 bridge, 2 miles southeast of Winslow	Current study, 1992
91	Gibson	Ditch, 2 miles east of Francisco, Route 64	Page, *et al.*, unpublished
92	Gibson	Ditch, 2 miles east of Kirkville	Page, *et al.*, unpublished
93	Gibson	Tributary of the Patoka River, 2.5 miles northeast of Princeton	Page, *et al.*, unpublished
94	Gibson	Tributary of the Patoka River, 3.5 miles west of Wheeling	Page, *et al.*, unpublished
95	Orange	Bacon Creek, Bacon	Page, *et al.*, unpublished
96	Orange	Tributary of the Patoka River, 5 miles southwest of French Lick	Page, *et al.*, unpublished
97	Pike	Flat Creek, 3 miles northwest of Otwell	Page, *et al.*, unpublished
98	Pike	Tributary of the Patoka River, 0.5 mile west of Pikeville, Highway 257	Page, *et al.*, unpublished
99	Pike	Tributary of the Patoka River, 1 mile southwest of Glezon, Rt 57	Page, *et al.*, unpublished
100	Crawford	Tributary of Patoka Lake, 1.5 miles southwest of Wickliff	Page, *et al.*, unpublished
101	Dubois	Tributary of the Patoka River, Ireland	Page, *et al.*, unpublished
102	Pike	Hat Creek, CR 50 E, 1 mile east of Coe	Current study, 1992
103	Pike	Honey Creek, Blackfoot Road, 2.5 miles north of Spurgeon	Current study, 1992
104	Gibson	West Fork Keg Creek, SR 64	IDOT, unpublished 1993
105	Gibson	East Fork Keg Creek, CR 125 S	IDOT, unpublished 1993
106	Gibson	East Fork Keg Creek, CR 1050 E	IDOT, unpublished 1993
107	Gibson	Turkey Creek, SR 64, 0.5 mile east of Oakland City	IDOT, unpublished 1993
108	Gibson	Old Wabash and Erie Canal, CR 50 N	IDOT, unpublished 1993
109	Gibson	East Fork Keg Creek, Claybank Road	IDOT, unpublished 1993
110	Pike	Robinson Creek, CR 100 S	IDOT, unpublished 1993
111	Pike	Flat Creek, Winslow-Patoka Road	IDOT, unpublished 1993
112	Pike	Flat Creek, SR 57, 1 mile north of Glezen	IDOT, unpublished 1993
113	Pike	Flat Creek, CR 50 S, east of Glezen	IDOT, unpublished 1993
114	Pike	Flat Creek, CR 275 W	IDOT, unpublished 1993
115	Gibson	Hurricane Creek, 0.75 mile west of Dongola	IDOT, unpublished 1993
116	Gibson	East Fork Keg Creek, McCullough Road	IDOT, unpublished 1993
117	Pike	Lick Creek, CR 300 S, 0.5 mile west of Survant	Current study, 1993

when conductivity was greater than 1000 µS, using various length seines with a 1/8-inch mesh. Sample distances were at least 15 times the wetted stream width with a minimum distance of 50 m. Sample distances for larger mainstem sites ranged from 500-1000 m and included two boat passes on both shores. Sampling was conducted in an upstream direction in small- to mid-sized streams and in both directions in large mainstem segments. The objective of collecting this data was to document species occurrence in a representative sample of a particular reach, recognizing that all rare species may not be collected as stream size increases. In conjunction with the fish community collections, habitat was assessed by the qualitative habitat evaluation procedure (Rankin, 1989).

RESULTS AND DISCUSSION

The Patoka River is a very diverse stream represented historically by 90 species of fish (Table 2). This represents 22.6% of the entire State fauna (Simon, *et al.,* 1992). Significant portions of the community have remained stable during the last century. However, some community changes have occurred which are important to document in light of the addition of the lower Patoka River as a National Wildlife Refuge.

Historical Distribution (Pre-1900). The Patoka River before 1900 contained several species characteristic of the clear streams of the Wabash River Lowlands. Data from the turn of the century are limited and are based on only three localities (Jordan, 1890; Moenkhaus, 1896). Species such as flier (*Centrarchus macropterus*), brindled madtom (*Noturus miurus*), bluebreast darter (*Etheostoma camurum*), harlequin darter (*Etheostoma histrio*), slenderhead darter (*Percina phoxocephala*), and dusky darter (*P. sciera*) were present in the drainage. Judging from the extant museum specimens, Patoka River sites were sampled frequently, and the number of specimens seems adequate to document the majority of species previously occurring in the lower Patoka River. The only species not represented by multiple collections is the bluebreast darter (Simon, pers. obs.). Based on historical information (Jordan, 1890), the bluebreast darter was probably not a significant component of the Patoka River fauna. The bluebreast darter is usually associated with gravel-cobble riffle habitats (Trautman, 1982) and usually requires the clean interstitial spaces of elevated cobble and boulders to clump eggs during reproduction (Page and Simon, 1988). Typically, the bluebreast darter occurs in the glacial till areas of the last Wisconsian advance. The Patoka River probably never had significant amounts of this microhabitat, because it was dominated by lowland habitats and shale outcrops. The presence of the other five species, which are characteristic of clear streams, is consistent with the expected fauna of the Wabash River lowlands.

Community Changes Between 1940 and 1945. Hubbs and Lagler (1942), Lagler and Ricker (1942), and Gerking (1945) made 7 collections between 1940 and 1945. The loss of brindled madtom, bluebreast darter, harlequin darter, and dusky darter prior to this time indicates that significant changes were already occurring in the drainage. Species such as brindled madtom, slenderhead darter, and sand shiner (*Notropis ludibundis*) were collected for the last time during this period. Additional species documented by these investigators include paddlefish (*Polyodon spathula*), yellow bass (*Morone mississippiensis*), rock bass (*Ambloplites rupestris*), smallmouth bass (*Micropterus dolomieui*), rainbow darter (*Etheostoma

Table 2. A listing of historical and present fish species collected from the Patoka River drainage. The numbers represent sites listed in Table 1. The sequence of species follows Simon, *et al.* (1992).

Lepisosteus platostomus	4, 14, 16, 17, 19, 24, 27, 36-43, 47, 56
L. osseus	4, 17, 20, 42, 56
L. oculatus	4, 23, 37, 38, 42, 54, 56, 57
Amia calva	3, 4, 8, 13, 15-23, 27, 36, 37, 39, 41, 43, 51, 54, 56, 77
Polyodon spathula	4
Esox americanus	2, 3, 8-12, 22-25, 27-31, 54, 62, 70, 73, 74, 76, 78, 83, 84, 98, 102, 111
E. lucius	23
Umbra limi	3, 8
Dorosoma cepedianum	2, 4, 5, 13, 14, 16, 18-21, 24, 27, 36-40, 42-51, 54, 56, 77
D. petenense	89
Campostoma anomalum	2, 6, 11, 30-33, 35, 60, 71, 84, 93, 95, 98, 100, 104, 109, 110, 116
Cyprinella spiloptera	4, 5, 10, 13, 42-48, 50-55, 78, 115
C. whipplei	4, 5, 42, 44, 45, 48-51, 55, 115
Cyprinus carpio	4, 5, 13-17, 19-24, 27, 29, 31, 36-43, 45, 47-51, 56, 59, 115
Ericymba buccata	5, 6, 9, 20, 28, 30-33, 35, 74, 106
Hybognathus hayi	94
H. nuchalis	2-9, 24, 28, 30, 31, 33, 44-46, 56
Luxilus chrysocephalus	1, 6, 9, 11, 12, 22, 23, 32-35, 71, 74, 95, 113
Lythrurus fumeus	45, 50, 51, 54, 55, 56, 78
Lythurus umbratilis	2, 3, 8-12, 28-30, 32, 33, 35, 60, 76, 78, 97, 113
Notemigonus crysoleucus	3, 4, 5, 7, 8, 14, 19, 21, 24, 28, 29, 33, 34, 36, 40, 78, 107, 109, 115
Notropis anogenus	55
N. atherinoides	1, 2, 4, 13, 21, 24, 44-46, 51, 56
N. blennius	4, 49, 55, 89
N. ludibundus	5
N. texanus	22(?), 28(?), 30(?), 43(?)
N. volucellus	2, 10, 36, 37, 41
Opseopodeus emiliae	2-4, 8, 30
Phenacobius mirabilis	2, 5, 6, 9, 28-31, 33, 46, 49, 50, 55, 105, 106
Phoxinus erythrogaster	95, 96
Pimephales notatus	2-6, 8, 9, 11, 12, 17, 19, 20, 22-24, 28, 30-35, 43, 44, 47, 50-55, 59, 60, 71, 74, 81, 89, 91, 96, 104-106, 116
P. promelas	59
P. vigilax	2, 4-6, 44-47, 51
Rhinichthys atratulus	96
Semotilus atromaculatus	9, 28-35, 50, 60, 62, 63, 71, 73, 74, 76, 83, 84, 89, 91-93, 95-97, 100, 102, 104, 106, 107, 109, 110, 112-114, 116

Carpiodes carpio	4, 13, 22, 47, 48, 54, 56
C. cyprinus	5, 6, 15, 20, 24, 38-43, 49
C. velifer	15, 49
Catostomus commersoni	11, 28-31, 33-35, 77, 89, 100
Erimyzon oblongus	3, 8, 9, 11, 28, 30-35, 60, 74, 76, 78, 84, 111
Ictiobus bubalus	4, 16-23, 27, 36-43, 49, 54, 56
I. cyprinellus	4, 5, 16, 19, 20-23, 27, 39-43, 48, 54, 56
I. niger	4, 40, 42, 43, 56
Minytrema melanops	3, 4, 8, 21, 22, 29, 34, 111
Moxostoma anisurum	47, 54
M. erythrurum	12, 21-23, 35, 39, 41, 42
M. macrolepidotum	49
Ameiurus melas	2-4, 8, 19, 24, 28-31, 33, 59, 62, 81, 89
A. natalis	2, 6, 23, 24, 28-31, 36, 57, 59, 60, 62, 70, 71, 73, 76-78, 81, 89, 91, 97, 98
A. nebulosus	3, 8, 11, 23, 59, 70
Ictalurus punctatus	1, 2, 4, 6, 14, 20, 36-43, 45-51, 54-56
Noturus gyrinus	4, 17, 24, 28-30, 51, 55, 78
N. miurus	1, 2, 6, 9
Pylodictis olivaris	1, 2, 4, 36-43, 59
Aphredoderus sayanus	3, 8, 9, 11, 20, 24, 28-30, 41, 59, 60, 62, 76, 78, 91, 93, 98
Fundulus dispar	49, 115
F. notatus	1-5, 7-13, 15, 16, 20, 21, 24, 27-37, 42-45, 47-49, 51, 54-56, 59, 60, 62, 63, 70, 71, 76, 78, 81, 89, 91, 97, 98, 102, 104-106, 110-116
Labidesthes sicculus	1, 2, 4, 44, 47, 49, 51, 52, 54, 105
Gambusia affinis	4, 37, 44, 45, 47, 48, 51-53, 56, 59, 78, 81, 82, 89, 91, 93, 94, 99, 101, 107, 110, 115-116
Morone chrysops	4, 13(?), 38
M. mississippiensis	4
Ambloplites rupestris	4, 12
Centrarchus macropterus	3, 6, 8, 10, 24, 27, 28
Lepomis cyanellus	2, 5, 6, 9, 11, 15-17, 19, 23, 24, 27-31, 33-35, 40, 41, 43, 44, 49, 51, 53-55, 59, 62, 71, 73, 76, 78, 81, 83, 84, 91, 93, 98, 100, 101, 110, 113-116
L. gulosus	2-5, 8, 21, 24, 36, 37, 40, 42, 43, 57, 59, 62, 70, 76, 78, 91, 98, 100, 115
L. humilis	2, 4, 5, 15, 24, 39, 42, 44, 48, 49, 54, 56
L. macrochirus	2-4, 7-9, 13-15, 17, 19, 20-24, 27-29, 31-34, 36-44, 47-49, 51, 54, 56, 57, 59, 60, 62, 70, 74, 76, 78, 81, 89, 93, 97-100, 103, 106, 114, 116
L. megalotis	1-5, 7-9, 11-14, 16-24, 27-35, 41, 45, 47-49, 51, 54-56, 60, 70, 71, 74, 76, 78, 97, 100, 106, 111-113
L. microlophus	14, 21, 23, 27, 62, 106
L. punctatus	40, 43, 56, 76, 78, 107
Micropterus dolomieui	12

M. punctulatus	5, 6, 12-14, 17, 20, 22, 23, 31, 32, 40-42, 44, 45, 47-49, 51, 54-57, 62, 78, 106
M. salmoides	4, 16, 17, 20, 23, 24, 27-29, 34, 36, 37, 42, 43, 49, 97
Pomoxis annularis	2-4, 6-8, 13-16, 18, 19, 21, 22, 27, 38, 39, 41-45, 49, 56
P. nigromaculatus	1, 4, 6, 14, 15, 17, 19-21, 23, 24, 27, 28, 36, 49
Etheostoma asprigene	4, 22, 29, 47, 48, 51, 54, 55
E. caeruleum	12
E. camurum	2
E. chlorosoma	2, 4, 5, 24, 28, 29, 34
E. gracile	2, 5, 47, 60, 78, 94, 98, 99, 104, 106, 107, 109, 111, 112, 114, 116
E. histrio	1
E. nigrum	1, 3, 6-9, 11, 12, 28-31, 60, 71, 74, 97
E. spectabile	31, 35, 95, 96, 100
Percina caprodes	1, 4, 12, 23
P. maculata	2, 3, 5-9, 53, 55, 97
P. phoxocephala	1, 3, 8
P. sciera	1
P. shumardi	4, 22
Stizostedion canadense	4, 13, 47
Aplodinotus grunniens	1, 4, 6, 20, 37, 44, 45, 47-49, 54
Cottus bairdi	12

caeruleum), and mottled sculpin (*Cottus bairdi*). The clearing of land for agriculture between 1900 and 1940 probably increased sediment loadings and turbidity in the drainage. Paddlefish and yellow bass were collected from Foots Pond, which was never connected with the Patoka River drainage. The fact that these species occurred in the Wabash River lowlands suggests that these species may have occurred in the Patoka River drainage, but the collection methods utilized in the Patoka River in the past would have made capture in an open system unlikely. The rock bass, smallmouth bass, rainbow darter, and mottled sculpin are all characteristic of upland, cool-water streams (Table 2). The change from clear, well-oxygenated waters to more turbid waters which absorb heat eliminated these species.

Community Changes Between 1945 and 1978. Hottell (1978) evaluated 23 stations in the mainstem Patoka River and its tributaries. During this period, four species were added to the faunal list, including redear sunfish (*Lepomis microlophus*), bluntnose darter (*Etheostoma chlorosoma*), northern pike (*Esox lucius*), and orangethroat darter (*Etheostoma spectabile*). After the creation of Patoka Lake, northern pike were stocked in the reservoir. Hottell's specimens were undoubtedly stocked specimens, since neither the previous investigators nor subsequent ones have ever found northern pike. The bluntnose darter is a lowland species, occurring over woody debris and heavy organic sediments. Watershed changes resulting from drastic land use modifications (i.e., channelization, oil exploration, and coal mining had increased turbidity, siltation of sediments, lateral erosion of the banks, and acidity during this period) may have enabled several species to invade the watershed and caused the demise of others.

Community Changes Between 1978-1994. Three times as much work has been conducted in the drainage since 1991 than had previously occurred over the last century. Stefanavage (1991), the current study, unpublished records by Lawrence Page (Illinois Natural History Survey), and unpublished records from the Indiana Department of Transportation (IDOT) have increased our knowledge of this drainage substantially. Nine new species were collected between 1978 and 1994 (Table 2): threadfin shad (*Dorosoma petenense*), cypress minnow (*Hybognathus hayi*), ribbon shiner (*Lythrurus fumeus*), pugnose shiner (*Notropis anogenus*), southern redbelly dace (*Phoxinus erythrogaster*), fathead minnow (*Pimpehales promelas*), blacknose dace (*Rhinichthys atratulus*), shorthead redhorse (*Moxostoma macrolepidotum*), and starhead topminnow (*Fundulus dispar*). The ribbon shiner was previously known only from a few small creeks in southwestern Indiana (Gerking, 1945). However, the significant range extension of the ribbon shiner documented during this study is probably a result of the previous misidentification of the ribbon shiner as the redfin shiner (*L. umbratilis*). Transport of fathead minnow into the drainage may be a result of bait-bucket release. Threadfin shad introductions were probably a result of immigration from reservoir habitats. Pugnose shiner, starhead topminnow, and shorthead redhorse represent species sensitive to siltation and acidity and are characteristic of reference conditions (Simon, 1991). The increased occurrrence of these species in the watershed may be an environmental indicator of recovery.

Significant effects of acid mine drainage have been observed throughout the South Fork Patoka River. No fish were found at any of the six South Fork Patoka River locations (sites 64-69) or in Houchin Ditch (site 80). No aquatic life was found at the unnamed tributary at CR 900 S bridge (site 58), the unnamed tributary at Sugar Ridge Road (site 61), Big Creek near Oatsville (site 72), Durham Ditch northwest of Scottsburg (site 75), the unnamed tributary north of Enos Lake (site 85), the unnamed tributary at Liberty Road (site 87), or Mill Creek at SR 364 (site 90). These stations were impacted by a variety of factors, including acid mine leachate, oil exploration, and significant erosion. Several stations with intermittent flow reflected heavily disturbed conditions due to the lack of water during most of the year. Hog Branch (site 79), the unnamed tributary at Sugar Ridge Road (site 86), Wheeler Creek (site 88), the old Wabash and Erie Canal (site 108), and Lick Creek (site 117) were dry during the sampling period.

The authenticity of several records are suspect. The weed shiner, *Notropis texanus,* was reported by Hottell (1978) and Stefanavage (1991) from the Patoka River (sites 22 and 43), Cup Creek (site 28), and Hunley Creek (site 30). The weed shiner typically occurs in habitats with an abundance of aquatic vegetation. This shiner is similar to the pugnose minnow in appearance. During the current investigations, no weed shiners were collected. Hottell (1978) reported pugnose minnow to be sympatric with the weed shiner at the Hunley Creek site (site 30). Until voucher specimens of the weed shiner are collected, the presence of this species is considered speculative. White bass (*Morone chrysops*) was reported from the mouth of the Patoka River by Hottell (1978). Although this record is probable, white bass is probably not a significant resident of the Patoka River. White bass has been reported as far upstream as Patoka River mile 33.5 (site 38) and from Foots Pond (site 4). The paddlefish reported from Foots Pond suggests that this species may have occurred at least in the mouth of the Patoka River mainstem. Both paddlefish and white bass should be considered tentative residents of the Patoka River, because they are more representative of the larger Wabash River.

Historically, 90 species have resided in the Patoka River drainage (Table 2). Significant land use changes over the last 100 years have reduced the number of residents (since 1991) to 70 fish species. Local species extinctions and rare occurrences of some taxa suggest that the Patoka River bottomlands and adjacent habitats are important for maintaining and preserving stable biological function and structure. The formation of the Patoka River National Wildlife Refuge will help preserve this fragile ecotype and enable species which need periodic bottomland hardwood forest flooding to complete their life history.

ACKNOWLEDGMENTS

The authors appreciate the comeradery and assistance of their colleagues in the field, especially Scott Fetters, Ed Price, Rusty Yeager, and Bob Dodd. Marianne Giolitto provided data entry and proof-reading support. Our sincere appreciation to the Indiana Department of Transportation for use of records from the Evansville to Indianapolis highway Environmental Impact Statement and to Lawrence M. Page, Illinois Natural History Survey, for unpublished records from southwestern Indiana. Partial funding was provided by the U.S. Fish and Wildlife Service, Division of Refuges and Wildlife.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 207-211

BEDROCK PALEOTEMPERATURE STUDY OF THE KENTLAND IMPACT SITE KENTLAND, INDIANA

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ABSTRACT: Conodont samples were collected from exposed strata in the Kentland Quarry to determine the thermal effects of an impacting body. A meteorite impact, such as proposed by Deitz (1947), should cause alteration of the conodont elements, especially those near the point of impact. Most of the Ordovician through Silurian elements recovered thus far are pale yellow and match the conodont alteration index (CAI) of 1.0 (Epstein, Epstein, and Harris, 1977). However, some elements recovered from the basal Silurian (Sexton Creek Limestone) have a CAI of 3.0. These results are similar to those of Votaw (1980) and suggest that only minor, if any, thermal alteration of the conodonts occurred as a result of the formation of the Kentland structure.

KEYWORDS: Conodonts, meteorite impact, paleotemperature.

INTRODUCTION

Located about 100 miles south of Chicago, the Kentland structure is exposed in the Newton Stone Company Quarry 2.5 miles east of Kentland, Indiana (Figure 1). The debate on the origin of the Kentland structure has lasted for more than a century (Gorby, 1886; Deitz, 1947; Tudor, 1971; Laney and Van Schmus, 1978). The structure has been called a Silurian reef (Gorby, 1886). Tudor (1971) claimed an endogenetic origin. However, no igneous rocks are present in the open quarry, and none has been found by coring operations. Shatter cones at the site suggest a meteorite impact origin. If the strata are rotated to their original position, the shatter cone apices point toward the sky (Dietz, 1947). If the site is compared with morphological and structural analogs produced by explosion cratering, the structure falls into the flat-floored, central-uplift crater type (Roddy, 1977). On comparing Kentland with other well-studied impact sites (e.g., Flynn Creek (Roddy, 1968, 1977), Wells Creek (Wilson and Stearns, 1968), and Decaturville (Offield and Pohn, 1977)), many structural and geophysical similarities are noted. At present, the quarry operation has exposed a 100,000 square meter area on the northwestern flank of the central uplift (Figure 2).

Ongoing studies (Nasser and Howe, 1993) are underway to determine the thermal effects of the meteorite on the conodonts at the Kentland impact site. The color alteration index (CAI) of Epstein, Epstein, and Harris (1977) was used to determine whether or not the conodonts had been thermally altered. The CAI value may range from 1 to 8. The higher numbers indicate that higher temperatures had been reached sometime after the deposition of the conodonts. The conodonts at Kentland should display significant alteration as a result of the heat generated by the meteorite impact.

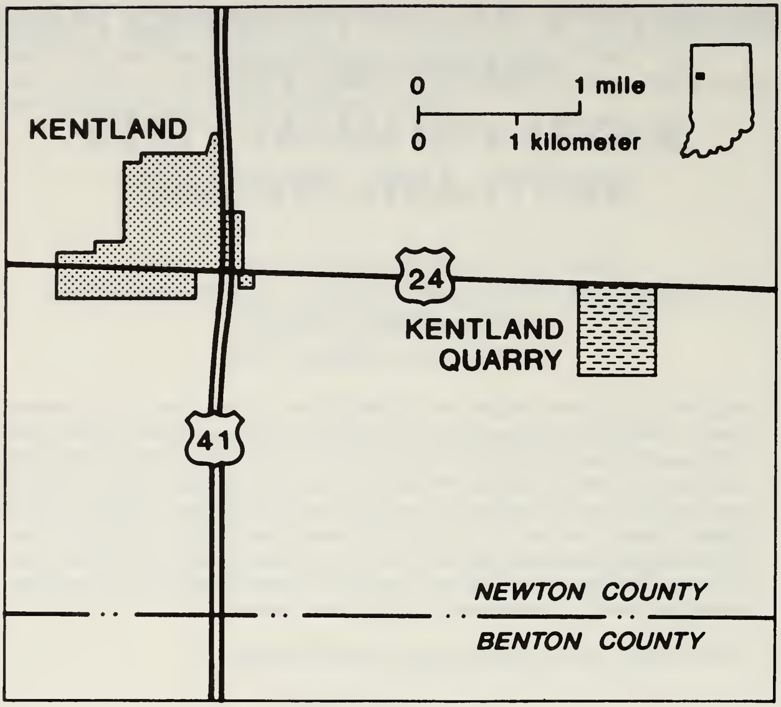

Figure 1. Location of the Kentland Quarry.

GEOLOGIC SETTING

About 50 different quarries are operating in Upper and Middle Silurian rock in northwestern Indiana and northeastern Illinois. The Kentland Quarry (Figure 2) is located in a complete sequence from the Lower Ordovician (Shakopee Dolomite) through Lower Silurian (Salamonie Dolomite) (Gutschick, 1983). The rocks at Kentland have been uplifted at least 700 m. The overall structure is approximately 12.5 km in diameter (Laney and Van Schmus, 1978). This tremendous uplift is an example of the effect of the enormous kinetic energy released by a large meteorite impact.

In general, northwestern Indiana has remained geologically stable for millions of years. The strata in most of Indiana are gently dipping and appear nearly horizontal to the naked eye (except in areas where the bedrock is draped over Silurian reefs). Indiana has a few isolated locations where conodonts have been altered to as high as CAI 6.0 (Harris, Rexroad, Lierman, and Askin, 1990). In Newton County, however, CAI values of 1.0 have been reported in the eastern part of the county (Rexroad and Droste, 1982). These low CAI values suggest the absence of other causes of conodont alteration, making the Kentland Quarry an excellent setting for testing whether or not meteorite impact affects conodonts.

At Kentland, because of the chaotic strata, the strike of the rocks depends on the block being studied. Generally, on the north and south flanks of the dome, the strikes are east-west, whereas on the east and west flanks of the dome, the

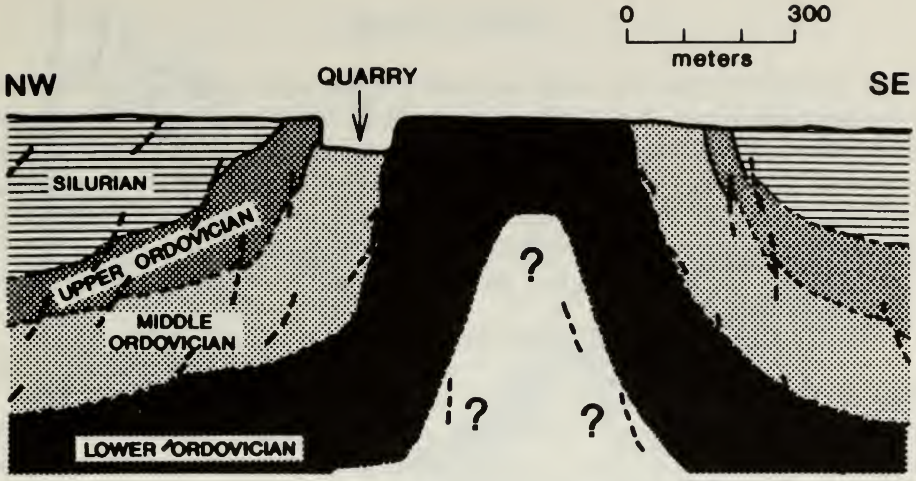

Figure 2. Location of the Kentland Quarry in the central uplift. The peak has been eroded (modified from Laney and Van Schmus, 1978).

strikes are north-south. The dips at the Kentland structure also vary markedly, ranging from 38 degrees to overturned bedding (Figure 3).

METHODS

Field Work. Samples of the Ordovician and Silurian units were taken across the structure to study the stratigraphic distribution of thermal activity. The approximate location of each sample was recorded on the geologic map prepared by Gutschick (1983). At each sample site, at least 10 kilograms of rock were collected, because quarry activity could destroy or cover up sample sites and prohibit later sampling. Ordovician (Shakopee Dolomite) samples were taken from the south-central part of the quarry. Additional Ordovician samples were taken along the west wall from a 6-foot thick dolomite member (Fort Atkinson Limestone) situated in the middle of the Maquoketa Shale. Silurian samples were also taken along the west wall of the quarry, because this wall was the only area where Silurian rocks were exposed. The Silurian units sampled were the Sexton Creek Limestone and the Salamonie Dolomite. Within these two formations, 17 different samples were collected at ten foot intervals.

Laboratory Work. Laboratory procedures were adopted from Kummel and Raup (1965). Ten percent aqueous glacial acetic acid was used to dissolve the samples. Instead of using bromoform (heavy liquid separation), the authors washed the conodonts in a set of sieves (2.5 phi, 3.0 phi, and 4.0 phi) to separate the processed rock fragments by size. Most conodonts were retained on the 3.0 phi sieve.

RESULTS

The Ordovician (Shakopee Dolomite) samples contained no conodonts or any other microfossils. Conodonts from the Fort Atkinson Limestone had a CAI of

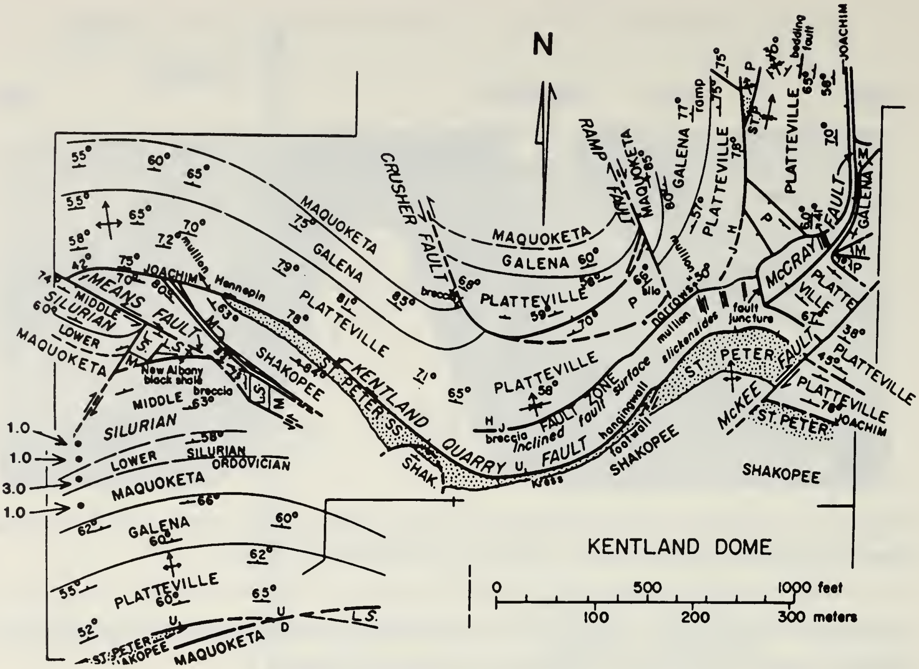

Figure 3. Geologic map of the Kentland Quarry (modified from Gutschick, 1983). Sample sites with CAI numbers are shown on the west side of the map.

1.0. From the Silurian, samples 4, 5, and 17 were processed, and all contained conodonts. The CAI values for these samples were: for sample 4, 1.0; for sample 5, 1.0; and for sample 17, 3.0. Samples 4 and 5 were from near the middle of the Salamonie Dolomite; and sample 17 was from the basal Sexton Creek Limestone near the Ordovician-Silurian contact.

DISCUSSION

The CAI values were plotted on the geologic map at the sample sites (Figure 3) to show the stratigraphic distribution of the thermal alteration as well as its horizontal distribution across the quarry. The variation pattern of the CAI numbers was unexpected, but its relationship with the thermal conductivity of the rock soon became apparent. Votaw (1980) sampled the Middle Ordovician Platteville and Galena Dolomite units and reported CAI numbers of 1.5. These data indicate that the massive dolomites situated on the northwest flank of the central uplift beneath the original flat-floored crater (which has been eroded away) acted as insulators. The shales interbedded with dolomites in the basal Silurian (Sexton Creek Limestone) may have conducted away some of the heat generated within the bedrock better than the dolomites. The authors plan to follow up this report with the CAI values obtained from sampling faults in the quarry and the Maquoketa Shale (i.e., Brainard Shale). A broader sampling across the quarry may provide greater insight into how heat was transmitted through the disturbed bedrock.

CONCLUSIONS

The data collected from the Kentland site show isolated thermal alteration beneath the crater floor. Most of the thermal energy was apparently dissipated by vaporization of the ejecta blanket and formation of the breccia lens along with minor thermal alteration of the target material within the structurally complex rocks beneath the crater floor. Comparative studies planned for Wells Creek and Meteor Crater may reveal how heat is transmitted through rocks at meteorite impact sites.

ACKNOWLEDGMENTS

The first author thanks his wife Lisa for understanding his being in the field and in the office for many hours, days, and nights. Special recognition goes to Leigh Ann Blake, Ryan Corman, Bill Hartwell, and Scott Huss for help in sampling. Carl Rexroad of the Indiana Geological Survey provided substantial help by confirming the alteration numbers of the conodonts.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 213-221

ADDITIONS TO THE FLORA OF SOUTHERN INDIANA, V and VI

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ABSTRACT: Fifty-eight taxa of vascular plants categorized as either 1) new to Indiana, 2) new to southern Indiana, or 3) rarely observed in southern Indiana were found during field inventories from 1990 through 1993. Those taxa new to Indiana are: *Asclepias viridis, Diodia virginiana, Eupatorium album, Lonicera sempervirens, Lygodium palmatum, Panicum annulum, Paspalum floridanum, Ranunculus sardous, Sedum pulchellum, Senna obtusifolia, Styrax grandifolius, Uvularia perfoliata,* and *Vitis rupestris. Carex woodii, Chloris verticillata, Hieraceum longipilum, Hypericum adpressum, Lycopodium obscurum, Lysimachia vulgaris, Panicum verrucosum, Panicum villosissimum, Potamogeton pusillus, Puccinellia pallida, Sida hermaphrodita,* and *Viburnum rafinesquianum* are new to southern Indiana. Those taxa rarely observed in southern Indiana include *Aristida purpurascens, Azolla* (cf.) *caroliniana, Bacopa rotundifolia, Bartonia paniculata, Carex gigantea, Carex lupuliformis, Cimicifuga rubifolia, Crotonopsis elliptica, Didiplis diandra, Dryopteris cristata, Eupatorium hyssopifolium, Eupatorium rotundifolium, Festuca paradoxa, Gentiana villosa, Hieraceum caespitosum, Helianthemum bicknellii, Juncus secundus, Leptochloa panicoides, Linum striatum, Ludwigia glandulosa, Lycopodium clavatum, Mikania scandens, Muhlenbergia capillaris, Rhexia mariana* var. *mariana, Rhynchospora corniculata, Sagittaria graminea, Satureja vulgaris* var. *neogaea, Scleria triglomerata, Senna occidentalis, Strophostyles leiosperma, Utricularia vulgaris, Woodwardia areolata,* and *Zosterella dubia.*

KEYWORDS: Distribution of rare plant species, Indiana flora, rare plant species.

INTRODUCTION

This publication represents numbers five and six in a series of bi-yearly reports presented at the Fall Meeting of the Academy on additions to the vascular flora of southern Indiana (Homoya, 1983, 1987; Homoya and Abrell, 1986; Homoya and Hedge, 1990). Southern Indiana as defined here is that area south of U.S. Highway 40 east of Indianapolis and U.S. Highway 36 west of Indianapolis. Endangerment status comes from *Indiana's Rare Plants and Animals: A Checklist of Endangered and Threatened Species* (Indiana Department of Natural Resources, 1993). For the most part, the nomenclature follows Gleason and Cronquist (1991). Natural region names follow Homoya, *et al.* (1985). Voucher specimens will be deposited in the herbarium at Indiana University in Bloomington.

SPECIES NEW TO INDIANA

***Asclepias viridis* Walter.** (Harrison County; 8 June 1993; *Homoya and Abrell 93-06-08-44*). Seven plants of this distinctive milkweed were found on an eroded, limestone barrens within the watershed of Little Mosquito Creek. The occurrence of the Ozark milkweed here is not too surprising given that it occurs in nearby Hardin County, Kentucky (Cranfill, 1991). This species has also been discovered in an old field in Jefferson County (P. MacMillan, pers. comm.).

Diodia virginiana **L.** (Gibson County; 1 August 1991; *Homoya and Abrell 91-08-01-101*: Harrison County; 25 July 1991; *C. Hedge, Homoya, et al. 91-07-25-91*: and Pike County; 3 October 1991; *Homoya and Abrell 91-10-03-221*). Scattered populations were found growing along the exposed borders of the Ohio and Patoka Rivers. Since the initial discoveries in 1991, this species has been collected at several additional locations along the Ohio River as far upriver as Switzerland County.

Eupatorium album **L.** (Perry County; 13 June 1991; *Homoya 91-06-13-34*). The white-bracted eupatorium is locally common west of Derby in remnant barrens and old fields. Its occurrence in Indiana is a northern range extension from known populations in Hardin County, Kentucky (Cranfill, 1991).

Lonicera sempervirens **L.** (Jefferson County; 15 June 1993; *Homoya and C. Hedge 93-06-15-51*). Deam (1940) did not accept this species as a member of our flora, neither as a native nor naturalized exotic. Numerous plants of the honeysuckle were found growing in a wet, acidic flatwoods in southwest Jefferson County. The site is of high natural quality and has exceptional diversity (e.g., *Maianthemum canadense, Isotria verticillata, Carex buxbaumii, Spiraea tomentosa, Viola lanceolata,* and *Eleocharis wolfii*). *Lonicera sempervirens* does not appear to be a recent escape, as it is not growing on the woods' edge nor near any evidence of a homesite. If not native here, *L. sempervirens* is at least naturalized and reproducing.

Lygodium palmatum **(Bernh.) Swartz.** (Ripley County; 19 August 1992; *Homoya, R. Hedge, and T. Hulvershorn 92-08-19-93*). Several large patches of climbing fern were found in a young regrowth flatwoods of red maple and sweet gum on the Jefferson Proving Ground (JPG). Wet, acidic flatwoods are relatively common at JPG and elsewhere in southeastern Indiana, so additional populations of this interesting fern may exist.

Panicum annulum **Ashe. (=** ***P. dichotomum*** **L. [Gleason & Cronquist]).** (Harrison County; 28 June 1989; *Homoya and C. Hedge 89-06-28-78*; and 19 May 1991; *Homoya, B. McKnight, and M. Sargent 91-05-19-18*). This distinctive grass was found at two separate barrens remnants in the Big Barrens Region of Harrison County. Although considered by some to be a variant of the common *Panicum dichotomum,* this grass appears morphologically distinct and has a fidelity to barrens (at least in Indiana).

Paspalum floridanum **Michx.** (Harrison County; 31 August 1990; *Homoya and R. Hedge 90-08-31-126*). This large bead-grass was found growing in a road shoulder and adjacent fields and pastures approximately three miles southwest of Corydon. The senior author has observed this species extending its range northward in Illinois for several years, and thus its appearance in Indiana is not surprising.

Ranunculus sardous **Crantz.** (Jefferson County; 4 May 1990; *Homoya and C. Hedge 90-05-04-8*). Large populations of this buttercup occur in agricultural fields and highway rights-of-way in southern Jefferson County. This European species is expected to spread and establish elsewhere in the State.

Sedum pulchellum **Michx.** (Johnson County; 6 June 1992; *Homoya and D. Zay 92-06-08-28*). The senior author has observed this stonecrop for over ten years at the Atterbury Fish and Wildlife Area, and it appears to be well established and persistent. Plants are quite common in the shallow soil on and bordering the numerous paved roads on the property. This species is native to rocky barrens in Kentucky and southern Illinois, but indigenous populations are unknown for Indiana.

***Senna obtusifolia* (L.) Irwin & Barneby**. (Pike County; 3 October 1991; *Homoya and Abrell 91-10-03-220*). Several plants of this species were found growing in the ballast and adjacent ditches along the Southern Railroad about two miles east of Winslow. The origin of these plants is unknown. They may be railroad waifs, but given that the species occurs naturally in lowland habitats (through which the track is placed) and that the species occurs in nearby southern Illinois (Mohlenbrock and Voigt, 1959), the population could be considered indigenous. In 1991, John Thieret (pers. comm.) also discovered a population of this species in Dearborn County.

***Styrax grandifolius* Aiton.** (Crawford County; 1 August 1990; *Homoya and C. Hedge 90-08-01-106*). Several shrubs of various sizes were observed growing on a dry, forested hilltop a few miles north of Leavenworth. The population appears natural, making it the northernmost occurrence for this species in the Midwest. The next closest population that the authors are aware of is in Alexander County, Illinois (Mohlenbrock, 1986).

***Uvularia perfoliata* L.** (Harrison County; 19 October 1990; *Homoya 90-10-19-168)*. This species has been reported by many authors over the years, but, as Deam (1940) stated, all are undoubtedly misidentifications of *U. grandiflora*. However, the senior author has seen three populations of bona fide *U. perfoliata* growing in deep southern Harrison County. This species differs from *U. grandiflora* by its smaller size, colonial habit, mostly glabrous leaves (note: the leaves of some individuals of *U. grandiflora* are glabrous), slightly later flowering period, occupation of drier habitats, and flowers with relatively untwisted tepals that are noticably glandular-papillose within. The fruiting capsules of the two are also very different (Braun, 1967). The species is on the very edge of its range in Indiana, extending northward from nearby Hardin County, Kentucky (Cranfill, 1991).

***Vitis rupestris* Scheele.** (Harrison County; 2 August 1990; *Homoya and C. Hedge 90-08-02-109*). Sand grape is a non-climbing grape that grows on rocky stream banks. Several vines were found growing in limestone and chert gravels bordering Indian Creek. This grape most closely resembles *V. riparia,* differing in its habit and leaf shape (*V. rupestris*' leaves are more reniform in shape).

SPECIES NEW TO SOUTHERN INDIANA

***Carex woodii* Dewey.** (Jennings County; 23 September 1992; *Homoya and C. Hedge 92-09-23-126*). This sedge was at one time thought to be very rare (Deam, 1940) and even threatened in the State (Aldrich, Bacone, and Homoya, 1986). However, field work (and an ability to recognize the species vegetatively) has shown otherwise. Seemingly every mesic forest north of Indianapolis contains this species, and several populations are known in southern Indiana. To date, the southernmost *C. woodii* was collected in Jennings County on the Jefferson Proving Ground.

***Chloris verticillata* Nutt.** (Daviess County; 19 September 1991; *Homoya 91-09-19-191*). Introduced from the western states, this grass is becoming more common in the State, especially in sandy, disturbed areas. The senior author has seen it growing in the lawns and waste areas of downtown Indianapolis. The Daviess County population was growing in a sandy cemetery.

***Hieraceum longipilum* Torr.** (Harrison County; 11 August 1992; *Homoya 92-08-11-92*). Previously known only from the far northern part of the State, 10-15 flowering plants of this species were observed growing in a remnant chert barrens in southern Harrison County. They were found as scattered individuals amongst the much more common *H. gronovii.*

***Hypericum adpressum* Barton.** (Daviess County; 18 September 1991; *Homoya and R. Hedge 91-09-18-188*). A large population of the state-endangered creeping St. John's-wort was discovered for the first time in southern Indiana by Cloyce Hedge, Hank Huffman, and Harold Allison. Homoya and R. Hedge collected it soon thereafter at the same location — a wet, sandy depression in the Plainville Sand Section of the Southwestern Lowlands Natural Region.

***Lycopodium obscurum* L.** (Jefferson County; 18 January 1990; *Homoya and R. Hedge 90-01-18-3*; Ripley County; 22 September 1992; *Homoya, C. Hedge, and D. Zay 92-09-22-109*). In the past four years, several populations of this clubmoss have been found in the wet, acidic flatwoods of the Muscatatuck Flats and Canyons Section of the Bluegrass Natural Region. Most, if not all, of these populations are the result of a recent range expansion phenomenon, as they typically grow in young forests that occupy previously cultivated ground.

***Lysimachia vulgaris* L.** (Harrison County; 30 July 1993; *Homoya, B. Abrell, and R. Hedge 93-07-30-66*: Switzerland County; not vouchered). This exotic species is apparently becoming more common in the U.S. as it invades wetlands and the shorelines of major watercourses. Our populations were found growing on the flood-scoured banks of the Ohio River.

***Panicum verrucosum* Muhl.** (Perry County; 30 August 1990; *Homoya and R. Hedge 90-08-30-125*). Hundreds of individuals of this distinctive annual grass were discovered on the borders of a small pond and wetland in the Shawnee Hills. The pond is on a ridge top and appears to be an old, long-abandoned farm pond. However, since the pond habitat supports numerous plants uncommon for the area, including *Sphagnum, Viola lanceolata, Platanthera clavellata, Rhynchospora corniculata,* and *R. capitellata,* it may be a natural depression. A pine plantation occurs next to the pond, which may account for the occurrence of the referenced species (perhaps the pine seedlings were wrapped in sphagnum moss, which contained the seeds of the plants listed above).

***Panicum villosissimum* Nash.** (Harrison County; 19 May 1991; *Homoya, B. McKnight, and M. Sargent 91-05-19-19*). This grass is common in a chert barrens remnant in the southern part of the County. *Panicum villosissimum* is a drought tolerant plant, which also occurs in the sand barrens of northern Indiana.

***Potamogeton pusillus* L.** (Pike County; 10 July 1991: *Homoya and Abrell 91-07-10-63*). Because of the undercollecting typical of pondweeds, this species is probably more common than records indicate. The species was found to be abundant in a slow-moving stream flowing through a wetland near the Patoka River.

***Puccinellia pallida* (Torr.) R.T. Clausen.** (Harrison County; 5 May 1991; *Homoya 91-05-18-13*). A sinkhole pond near Laconia harbors this mostly northern grass, which grows on the border of the pond with buttonbush, *Glyceria septentrionalis, Carex lupulina,* and *C. comosa.*

***Sida hermaphrodita* (L.) Rusby.** (Switzerland County; 6 August 1991; *Homoya and C. Hedge 91-08-06-122*). This tall perennial was first collected in southern Indiana by John Baird and Allison Cusick on 30 October 1990 (Cusick, pers. comm.). Subsequently, the authors collected this species at the same location, a roadside bank bordering the Ohio River. This mostly eastern species extends westward through Ohio and Kentucky along the Ohio River drainage.

***Viburnum rafinesquianum* Schultes.** (Franklin County; 24 May 1991; *Homoya and T. Brothers 91-05-24-25*). This species is apparently at the southern limit of its range in Indiana. Several shrubs were noted growing on steep, rocky, limestone slopes not far from Laurel.

SPECIES RARELY OBSERVED IN SOUTHERN INDIANA

***Aristida purpurascens* Poiret.** (Harrison County; 22 September 1993; *Homoya 93-09-22-94*). Numerous individuals of this three-awn grass occur in a remnant chert barrens in southern Harrison County. This grass was also seen at another barrens site in Perry County but was not collected.

***Azolla* (cf.) *caroliniana* Willdenow.** (Posey County; 14 August 1991; *Homoya and R. Hedge 91-08-14-132*). Thousands of individuals of this fern were found growing in the mud of a large, shallow pond just south of a levee road bordering the south side of Hovey Lake. The determination to species is tentative, as certain identification of *Azolla* species in our range requires inspection of the megaspores with a scanning electron microscope.

***Bacopa rotundifolia* (Michx.) Wettst.** (Washington County; 10 August 1992; *Homoya and Abrell 92-08-10-85*). Thick mats of this creeping, floating aquatic were found around the border of a sinkhole pond. The pond was within a horse pasture, but the pond border was not heavily disturbed, as there were few horses. This population is one of only two extant populations known to the authors.

***Bartonia paniculata* (Michx.) Muhl.** (Ripley County; 19 August 1992; *R. Hedge, Homoya, and T. Hulvershorn 92-08-19-122*; Jefferson and Jennings Counties; not vouchered). First found in Indiana in 1985 (Homoya and Abrell, 1986), this species has since been found to be abundant throughout most of the Jefferson Proving Ground. *Bartonia paniculata* grows in the young regrowth forests on the wet, acidic flats that are common at the property.

***Carex gigantea* Rudge.** (Posey County; 14 August 1991; *Homoya and R. Hedge 91-08-14-133*). This endangered sedge is known from two areas in the State, the sinkhole wetlands of Harrison County and the swamplands of the lower Wabash River. The authors were unaware of extant occurrences of *C. gigantea* in the lower Wabash until the discovery of two small populations in southern Posey County. Both populations were in overcup oak dominated swamps.

***Carex lupuliformis* Sartwell.** (Posey County; 14 August 1991; *Homoya and R. Hedge 91-08-14-134*). Closely resembling *Carex gigantea* and *C. lupulina, C. lupuliformis* is a rare sedge of swamps and floodplain forests. A small population was found growing in the proximity of *C. gigantea* in southern Posey County.

***Cimicifuga rubifolia* Kearney.** (Posey County; 11 August 1993; *Homoya, Abrell, and R. Hedge 93-08-11-67*). Over twenty- five sites were checked for this species during a status survey for the U.S. Fish and Wildlife Service. Two new populations were discovered, in addition to the one previously collected in Harmonie State Park (Homoya and Abrell, 1986). The population in the Park is near extirpation, owing to severe grazing pressure by white-tailed deer.

***Crotonopsis elliptica* Willd.** (Jennings County; 11 September 1992; *Homoya, et al. 92-09-11-103*). A small population of the elliptical rushfoil was discovered on the xeric bank of a gravel road in the Jefferson Proving Ground. This population is considerably disjunct from Spencer County, the only other location in the State for the species.

***Didiplis diandra* (Nutt.) A. Wood.** (Gibson County; 26 September 1991; *Homoya and R. Hedge 91-09-26-199*: Pike County; 18 September 1991; *Homoya and R. Hedge 91-09-18-181*). Water-purslane was found at several locations on the Patoka River floodplain during an inventory there for the U.S. Fish and Wildlife Service. Most populations were growing on exposed mud in the basins of river oxbows and swamps.

***Dryopteris cristata* (L.) A. Gray.** (Ripley County; 1 July 1992; *Homoya and C. Hedge 92-07-01-64)*. In southern Indiana, *Drypoteris cristata* is an uncommon fern of seep springs. Thus, it was a surprise to find it growing in a different habitat — wet, acidic flatwoods. At least two populations were discovered in flatwoods during an inventory of the Jefferson Proving Ground.

***Eupatorium hyssopifolium* L.** (Jackson County; 12 September 1991; *Homoya and R. Hedge 91-09-12-173:* Ripley County; 22 September 1992; *Homoya and C. Hedge 92-09-22-118*). This species continues to expand its range in Indiana by moving into the southeastern counties. In addition to the Ripley County collection, the species was also observed at several other locations within the Jefferson Proving Ground.

***Eupatorium rotundifolium* L.** (Ripley County; 19 August 1992; *R. Hedge, Homoya, and T. Hulvershorn 92-08-19-123*). Like *Eupatorium hyssopifolium,* this species is also increasing its range. First reported for Indiana by Homoya and Hedge (1990), *E. rotundifolium* was found to be locally common at the Jefferson Proving Ground.

***Festuca paradoxa* Desv.** (Perry County; 20 June 1991; *Homoya and S. Olson 91-06-26-53*). A small population of this grass was discovered in a limestone barrens west of Derby. Elsewhere, this species is known only from Cass and Posey Counties.

***Gentiana villosa* L.** (Harrison County; 2 August 1990; *Homoya and C. Hedge 90-08-02-107* (vegetative only); 21 September 1990; *Homoya and C. Hedge 90-09-21-147* (flowering)). This very rare gentian was thought to be extirpated in Indiana until it was discovered in a dry woods and regrowth forest near Indian Creek. At this site, the species is doing well, as evidenced by the presence of several dozen individuals.

***Helianthemum bicknellii* Fern.** (Harrison County; 24 June 1992; *Homoya, L. Casebere, and Abrell 92-06-24-49*). An extremely rare plant of southern Indiana, this species of frostweed occurs sparingly in a remnant chert barrens in southern Harrison County. The plant does well where few other plants can, viz., in sterile, acidic, dry soil.

***Hieraceum caespitosum* Dumort.** (Jefferson County; 11 June 1992; *Homoya and R. Hedge 92-06-11-34*). This hawkweed is abundant at the Jefferson Proving

Ground and is apparently spreading throughout much of southeastern Indiana. The species was discovered in Jennings County in 1989 (Homoya and Hedge, 1990). This discovery was the first report of the species from southern Indiana.

***Juncus secundus* P. Beauv.** (Perry County; 30 August 1990; *Homoya and R. Hedge 90-08-30-119*). This state-endangered rush occurs sparingly in the exposed, acidic clay of an old field west of Derby. The old field, abandoned decades ago before purchase by the Hoosier National Forest, is home to numerous native barrens species, that are apparently re-invading the site from nearby barrens remnants.

***Leptochloa panicoides* (C. Presl.) A. Hitchc.** (Posey County; 13 August 1991; *Homoya and R. Hedge 91-08-13-128*). A southern grass, *Leptochloa panicoides* was last collected in Indiana in 1920 by C.C. Deam. His collection site was Pitcher's Lake in Posey County. Several years of searching at Pitcher's Lake failed to reveal the grass, but in 1991, a sizable population was discovered growing at a different oxbow lake not far from Pitcher's Lake.

***Linum striatum* Walter.** (Ripley County; 22 September 1992; *Homoya and C. Hedge 92-09-22-115*). This uncommon flax was found growing at several locations in wet, acidic flatwoods on the Jefferson Proving Ground. The flatwoods community is young regrowth, and considerable light reaches the understory.

***Ludwigia glandulosa* Walter.** (Posey County; 16 July 1991; *Homoya and R. Hedge 91-07-16-64*). Once thought to be extirpated in the State (Aldrich, Bacone, and Homoya, 1986), at least four populations of this species are now known, all in deep southern Posey County. Roadside ditches and ephemeral pools in flatwoods are the habitats.

***Lycopodium clavatum* L.** (Jefferson County; 18 January 1990; *Homoya and R. Hedge 90-01-18-2*). This species appears to have recently spread into southern Indiana, especially in regrowth flatwoods in the southeastern part of the State. Several additional populations were observed on the Jefferson Proving Ground and elsewhere in southeastern Indiana. The range expansion phenomenon, first into northern and now into southern Indiana, must be relatively recent, as Deam (1940) did not list the species for our flora.

***Mikania scandens* (L.) Willd.** (Pike County; 19 September 1992; *Homoya and R. Hedge 91-09-19-192*). The population reported by Homoya (1983) from Pike County was revisited in 1991 after a nine year hiatus. A comparison of notes regarding population size indicates that the plants are reproducing and spreading. The species is now abundant within a ¼ mile radius of the original population.

***Muhlenbergia capillaris* (Lam.) Trin.** (Harrison County; 18 October 1990; *Homoya 90-10-18-164*). This species is a beautiful, but rare, grass of barrens environments. Previously known only from collections east of Elizabeth (now considered extirpated there due to quarry activity), a few clumps were recently discovered in a remnant limestone barrens at Wyandotte Woods.

***Rhexia mariana* L. var. *mariana*.** (Jefferson County; 22 July 1992; *Homoya and R. Hedge 92-07-22-68*). All previous collections of this species in Indiana have been from the southwestern portion of the State. A large population was discovered in a wide, grassy shoulder of a road within the Jefferson Proving Ground.

***Rhynchospora corniculata* (Lam.) A. Gray.** (Perry County; 30 August 1990; *Homoya and R. Hedge 90-08-30-121*: Posey County; 16 July 1991; *Homoya and R. Hedge 91-07-16-69*). This stout sedge was discovered growing in *Sphagnum* bordering a small pond in the Hoosier National Forest. The species was growing with other plants unusual for the area, including *Panicum verrucosum* and *Rhynchospora capitellata.* In Posey County, a few plants were found in an open, wet depression within a flatwoods.

***Sagittaria graminea* Michx.** (Pike County; 2 October 1991; *Homoya and Abrell 91-10-02-213*). Several individuals of the grass-leaved sagittaria were found growing in an oxbow of the Patoka River. This species was growing with another uncommon plant, *Didiplis diandra.*

***Satureja vulgaris* (L.) Fritsch var. *neogaea* Fern.** (Posey County; 12 August 1993; *Homoya, L. Gray, and R. Hedge 93-08-12-68*). This variety of wild basil, apparently native to North America, was collected from an old field on a ridge bordering the Wabash River south of New Harmony.

***Scleria triglomerata* Michx.** (Harrison County; 14 June 1991; *Homoya and Abrell 91-06-14-36*). A population of several hundred culms occurs in a remnant chert barrens in southern Harrison County. Other unusual plants in this barrens are *Helianthemum bicknellii, Hieraceum longipilum,* and *Panicum annulum.*

***Senna occidentalis* (L.) Link.** (Pike County; 3 October 1991; *Homoya and Abrell 91-10-03-219*). Several plants of this impressive legume were found growing in ballast along a railroad track near the Patoka River. This species is probably an introduction to Indiana, but our understanding of its origin is inconclusive. Deam (1940) considered it native, but some authorities consider it an Old World endemic (Gleason and Cronquist, 1991).

***Strophostyles leiosperma* (T. & G.) Piper.** (Jennings County; 11 September 1992; *Homoya, et al. 92-09-11-102*). This uncommon vine was located on the open, sterile bank of a gravel road on the Jefferson Proving Ground. This population is disjunct from other populations in the State, as is the plant growing with it, *Crotonopsis elliptica.*

***Utricularia vulgaris* L.** (Pike County; 10 July 1991; *Homoya and Abrell 91-07-10-61*). This species, Indiana's largest yellow-flowered bladderwort, is very rare in southern Indiana; it is much more common in the northern part of the State. At least two populations were found growing in shallow "dead" swamps (recently flooded areas where standing dead timber is present) along the Patoka River. In these places, one can also find the uncommon *Utricularia gibba.*

***Woodwardia areolata* (L.) Moore.** (Jefferson County; not vouchered: Jennings County; 22 July 1992; *Homoya and R. Hedge 92-07-22-66*: Ripley County; 11 June 1992; *Homoya and R. Hedge 92-06-11-32*). Although not common, *Woodwardia areolata* was observed at several sites within the Jefferson Proving Ground. All populations were growing in wet, acidic flatwoods of young age. This species is apparently still spreading in Indiana, as evidenced by several populations discovered since its initial report for the State (Homoya, 1983).

***Zosterella dubia* (Jacq.) Small.** (Jefferson County; 6 August 1991; *Homoya and C. Hedge 91-08-06-121*). This aquatic plant was discovered growing in shallow water at the shore of the Ohio River near Hanover. Although rather common in lakes and streams in northern Indiana, *Zosterella* is quite rare in the south.

ACKNOWLEDGMENTS

The authors wish to acknowledge the U.S. Fish and Wildlife Service (U.S.F.W.S.) and The Nature Conservancy for funding a rare plant inventory of the proposed Patoka National Wildlife Refuge during which many of the species described above were found. A special thanks to Bill McCoy of the U.S.F.W.S. and Denny McGrath of the Indiana Chapter of the The Nature Conservancy for their interest and assistance. The authors are also grateful for the funding provided by the Department of the Army for the rare plant inventory at the Jefferson Proving Ground. They are particularly appreciative of Ken Knouf for assistance in that project. Status surveys of federal candidate species were funded by the U.S.F.W.S.; Bill Harrison of the U.S.F.W.S. and Ken Nettles of the Indiana D.N.R. are thanked for their help in coordinating funding for these surveys. Thanks also go to the Indiana Department of Natural Resources, Division of Nature Preserves, and the Natural Heritage Data Center for supporting and encouraging field inventory work. Review comments by Lewis Johnson are also appreciated.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 223-232

SOUTHERN INDIANA PLANT DISTRIBUTION RECORDS AND NOTES ON THE ENDANGERED, THREATENED, AND RARE VASCULAR PLANT SPECIES IN THE PROPOSED STATE PARK AREAS OF THE INDIANA ARMY AMMUNITION PLANT

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ABSTRACT: Students in botany classes at Indiana University Southeast as well as individual collectors have found 88 new vascular plant records for Clark, Floyd, Harrison, Scott, and Washington Counties in southern Indiana. Most of the Clark County collections are from the Indiana Army Ammunition Plant. The State/County record vouchers and other collections cited are in the Indiana University Herbarium at Bloomington. Noteworthy collections are discussed. A listing (as of 1994) of Indiana endangered, threatened, and rare vascular plant species at the Charlestown State Park site and a leased park site within the Indiana Army Ammunition Plant is also provided and discussed.

KEYWORDS: Charlestown State Park, Clark County, endangered, threatened, rare — vascular plants, reports — vascular plants, southern Indiana County/State records.

INTRODUCTION

Distribution records and noteworthy species are listed for Clark, Floyd, Harrison, Scott, and Washington Counties in southern Indiana. Genera are in the order of their appearance in the *Flora of Indiana* (Deam, 1940); species within each genus are alphabetical with county and collector. Nomenclature conforms with Gleason and Cronquist (1991), except as noted. The indications of Indiana endangered (e), threatened (t), or rare (r) follow *Indiana's Rare Plants and Animals* (Indiana Department of Natural Resources, 1993).

The senior author began an annual botanical survey in the secured area at the north end of the Indiana Army Ammunition Plant (IAAP) in March 1977 with the permission of the U.S. Army. The survey covers land now owned by the State (the proposed Charlestown Park site) containing Rose Island and the Devil's Backbone next to the Ohio River (Charlestown and Owen Quadrangles) and managed by the Department of Natural Resources (DNR), Division of State Parks. Also included in Maxwell's survey are approximately one thousand acres adjoining IAAP, most of which is leased to the State. The leased parcel includes two cedar limestone glades (Maxwell, 1987).

The survey's initial purpose was educational — to provide vascular plant vouchers for a Kentuckiana reference collection in the Indiana University Southeast Herbarium (JEF). With direction from the DNR, Division of Nature Preserves, Indiana Natural Heritage Program, the focus shifted from simply collecting and identifying the local flora to a search for state and federally listed endangered, threatened, and rare vascular plant species. Those found within Maxwell's survey area as of December 1994 are listed and discussed below. An ongoing survey of the entire IAAP is being conducted by Michael A. Homoya, Botanist, Indiana DNR, Nature Preserves.

METHODS AND MATERIALS

Collections were made using conventional methods and materials. The specimens were processed, the pertinent literature checked, and primary determinations made at JEF. Voucher specimens for all new records and noteworthy collections were sent to the Indiana University Herbarium in Bloomington (IND) for confirmation and eventual incorporation into their permanent collection. Methods and criteria for listing Indiana's endangered, threatened, and rare vascular plant species have been discussed by Bacone and Hedge (1980), Bacone, Crovello, and Hedge (1981), and Aldrich, Bacone, and Homoya (1986).

Deam's anecdotal notes about collection sites in his published works, on his mounted collection labels, and his additional notes and collection route maps at IND are invaluable guides in the search for listed plants. The Indiana DNR, Nature Preserve vouchers are also at IND.

SOUTHERN INDIANA STATE/COUNTY RECORDS AND NOTEWORTHY COLLECTIONS

The following species with their counties, collectors, and status (if appropriate) were collected and identified:

Juniperus virgiania L. var. *crebra* Fern., Clark, *Maxwell 2797*

Asplenium x *ebenoides* R.R. Scott., Clark, *Porter s.n.*

Sparganium americanum Nutt., Harrison, *Schoen s.n.*

Sagittaria rigida Pursh., Clark, *Lee 28*

Chloris verticillata Nutt., Clark, *Maxwell 3010*

Digitaria ciliaris (Retz.) Koeler, Floyd, *Maxwell 2893*

Digitaria sanguinalis (L.) Scop., Floyd, *Maxwell 2894*

Eleusine indica (L.) Gaertn., Floyd, *Maxwell 2892*

Setaria faberi R. Herrm., Floyd, *Maxwell 2891*

Setaria geniculata (Lam.) P. Beauv. (e), Harrison, *Lawton 13*

Cyperus flavescens L., Floyd, *Maxwell 2912*

Commelina virginica L., Clark, *Maxwell 3057*

Allium burdickii (Hanes) A.G. Jones (Mohlenbrock 1986), Clark, *Maxwell 2977* (*Allium tricoccum* Aiton var. *burdickii* Hanes (Gleason & Cronquist, 1991))

Allium sativum L., Harrison, *Kepley 68*

Allium tricoccum Aiton var. *tricoccum*, Clark, *Maxwell 2975*

Asparagus officinalis L., Harrison, *Schoen s.n.*

Hemerocallis fulva (L.) L., Clark, *Hardman 61*

Ornithogalum umbellatum L., Floyd, *Weatherholt 886A*

Trillium flexipes Raf., Washington, *Emmert 173*

Trillium flexipes Raf. f. *Walpolei* (Farw.) Fern. (Fernald, 1950), Clark, Maxwell observed; Washington, *Emmert 173*

Liparis liliifolia (L.) Rich., Floyd, *Maxwell & Emmert 2887*

Platanthera peramoena (Gray) Gray (Mohlenbrock, 1986), Floyd, *Maxwell 1702*

Spiranthes cernua (L.) Rich., Washington, *Emmert 135*

Spiranthes tuberosa Raf. var. *tuberosa,* Clark, *Maxwell 2865*

Alnus serrulata (Aiton) Willd., Floyd, *Chambers 53*

Ulmus americana L., Floyd, *A. Johnson 11*

Maclura pomifera (Raf.) C.K. Schneider, Floyd, *Weatherholt 1550*

Boehmeria cylindrica (L.) Swartz, Clark, *Maxwell 3055*

Iresine rhizomatosa Standley (t), Clark, *Maxwell & Homoya 3056A*

Portulaca oleracea L., Clark, *Maxwell 3028*

Clematis virginiana L., Clark, *Maxwell 2925*

Cimicifuga racemosa (L.) Nutt., Clark, *Maxwell 3012*

Hepatica acutiloba DC., Washington, *Emmert 165*

Berberis thunbergii DC., Clark, *Maxwell 1823*

Caulophyllum thalictroides (L.) Michx., Clark, *Lyons 40*

Corydalis flavula (Raf.) DC., Washington, *Emmert 155*

Arabidopsis thaliana (L.) Heynh., Floyd, *Maxwell s.n.*

Dentaria heterophylla Nutt. (Fernald, 1950), Scott, *Zuckschwerdt s.n.*

Descurainia pinnata (Walter) Britton, Clark, *Maxwell 2237*

Diplotaxis tenuifolia (L.) DC., Floyd, *Maxwell s.n.*

Nasturtium officinale R. Br. (Mohlenbrock, 1986), Floyd, *Weatherholt 1015*

Mitella diphylla L., Washington, *Emmert 312*

Potentilla simplex Michx., Floyd, *Speth 16*

Rosa multiflora Thunb., Harrison, *Lawton 76*

Amorpha fruticosa L. var. *angustifolia* Pursh. (Mohlenbrock, 1986), Clark, *Maxwell 1589*

Lezpedeza cuneata (Dum. Cours.) G. Don., Clark, *Maxwell 1592*; Harrison, *Schoen 111*

Melilotus officinalis (L.) Pallas., Washington, *Emmert 235*

Robinia hispida L., Floyd, *Kruer 139*; Washington, *Emmert 297*

Geranium carolinianum L., Floyd, *Hahn 33*

Geranium maculatum L., Floyd, *Weatherholt 985*

Oxalis violacea L., Washington, *Emmert 178*

Acalphya deamii (Weatherby) Ahles. (t), Clark, *Maxwell & Homoya 3052*

Aesculus glabra Willd. var. *glabra*, Washington, *Emmert 199*

Parthenocissus quinquefolia (L.) Planchon, Floyd, *Barker 74*

Vitus riparia Michx., Clark, *Maxwell & Emmert 2911*

Hibiscus syriacus L., Harrison, *Schoen s.n.*

Malva neglecta Wallr., Harrison, *Schoen s.n.*

Viola rafinesquii Greene., Washington, *Emmert 159*

Viola striata Aiton., Floyd, *Weatherholt 843*

Aegopodium podagraria L., Floyd, *Maxwell 2883*

Vinca minor L., Floyd, *Weatherholt 823*

Asclepias syriaca L., Clark, *Waterman 31*

Matelea obliqua (Jacq.) Woodson (r), Clark, *Maxwell 1683* (= *Gonolobus obliquus* (Jacq.) Schultes (Fernald, 1950))

Mertensia virginica (L.) Pers., Washington, *Emmert 156*

Glechoma hederacea L., Washington, *Emmert 189*

Lamium amplexicaule L., Washington, *Emmert 150*

Leonurus cardiaca L., Floyd, *Weatherholt 1013*

Perilla frutescens (L.) Britton, Harrison, *Schoen s.n.*

Nepeta cataria L., Clark, *Maxwell & Emmert 2910*

Scutellaria elliptica Muhl., Floyd, *Weatherholt 722*

Datura wrightii Regel. ?? c.f. discussion, Harrison, *Schoen s.n.*

Datura stramonium L., Washington, *Emmert 261*

Physalis longifolia Nutt., Floyd, *Maxwell 2913*

Agalinis purpurea (L.) Pennell, Clark, *Maxwell 3007*

Mimulus alatus Ait. f. *albiflora* House (Fernald, 1950), Floyd, *Maxwell 2093*

Mimulus ringens L., Floyd, *Maxwell & Emmert 2888*

Veronica arvensis L., Floyd, *Speth 116*

Veronica peregrina L. var. *peregrina*, Floyd, *Weatherholt 876*

Catalpa speciosa Warder (r), Clark, *J.A.M. 60*

Justicia americana (L.) M. Vahl, Washington, *Emmert 222*

Galium tinctorium L., Clark, *Maxwell & Emmert 2908*

Lonicera maackii (Rupr.) Maxim, Clark, *Maxwell 2951*

Dipsacus sylvestris Hudson, Clark, *Maxwell 3031*

Lobelia siphilitica L. var. *siphilitica* f. *albiflora* Britt. (Fernald, 1950), Clark, *Maxwell 3009*

Sicyos angulatus L., Clark, *Maxwell 3043*; Floyd, *Maxwell 3011*; Washington, *Emmert 137*

Aster pilosus Willd., Washington, *Emmert 139*

Hieracium caespitosum Dumort, Clark, *Maxwell 2027*; Washington, *Emmert 221*

Matricaria matricarioides (Less.) Porter, Washington, *Emmert 190*

Rudbeckia laciniata L., Clark, *Maxwell 3001*

Tragopogon dubius Scop., Clark, *Calabro 87*; Harrison, *Schoen s.n.*; Washington, *Emmert 230*

POSSIBLE STATE RECORDS/NOTEWORTHY COLLECTIONS

Chloris verticillata **Nutt. (Poaceae).** Found in the IAAP, this specimen may represent the second State collection. The initial report was from Perry County.

Digitaria ciliaris **(Retz.) Koeler (Poaceae).** Although close to *D. sanguinalis* (L.) Scop., this species is considered distinct and is found in southern Indiana (Gleason and Cronquist, 1991). *Maxwell 2893* was submitted as a State voucher, since none was found nor were reports of any known at IND.

Setaria geniculata **(Lam.) P. Beauv. (Poaceae).** This grass was reported as a species new to Indiana by Homoya and Hedge (1990) in Perry County. The Harrison County collection may be the second for the State.

Allium tricoccum **Aiton and *A. burdickii* (Hanes) A.G. Jones (Liliaceae).** Both species are cited by Mohlenbrock (1986), but Gleason and Cronquist (1991) give only varietal status to *burdickii*. Homoya (pers. comm.) believes *burdickii* deserves species rank and pointed the differences between the two taxa out to the authors in the IAAP on 29 June 1994. The wooded slopes on both sides of Lick Creek in the IAAP lease area support large populations of both taxa. The locality is ideal for further study.

Datura wrightii **Regel. (Solanaceae).** This collection does not represent the common jimsonweed. Whether or not the specimen might represent *D. meteloides* DC. or *D. metel* L.(Deam, 1940) could not be determined from the herbarium sheet.

Lonicera maackii **(Rupr.) Maxim.** This large Asian honeysuckle shrub is well established along Loading Dock Road in the IAAP lease area and is moving into the open woods.

***Valerianella radiata* (L.) Dufr. (Valerianaceae).** This species was reported by Maxwell, *et al.* (1991) and was collected again within the IAAP in 1994 (*Maxwell 2945* on 4 May 1994 and *Maxwell 2953* on 18 May 1994). This species was excluded by Deam (1940). An examination of the Deam collections by their curator, Lewis Johnson, found that Deam did not annotate his *V. radiata* collections as *V. intermedia* "according to a recent revision" (Deam, 1940). Following Gleason and Cronquist (1991), *V. radiata* is maintained, and *V. intermedia* is placed in synonymy under *V. umbilicata* (Sulliv.) A. Wood. Based on Deam's original determinations of *Valerianella radiata* as found in his collections (IND), the species occurs in twenty-two counties in Indiana besides Clark County.

INDIANA ENDANGERED SPECIES WITHIN THE PARK SITES

***Asplenium resiliens* Kunze, Black-Stem Spleenwort (Aspleniaceae).** A few plants were discovered by Brian Abrell on the upper limestone cliffs of the Devil's Backbone south of the "fort." This species was vouchered by Homoya and Abrell (with Maxwell and Moberley) on 29 July 1994.

***Chaerophyllum procumbens* (L.) Cranz var. *shortii* T. & G., Wild Chervil (Apiaceae).** This species was found by Homoya (with Abrell and Maxwell) in the Jenny Lind Run area south of the proposed lease area in the IAAP proper. The species was vouchered by Homoya on 5 May 1994. *Maxwell 2950* was collected on 12 May 1994 in the lease area. The pubescent fruit variety was common at both of these locations.

***Leavenworthia uniflora* Michx., Michaux's Leavenworthia (Brassicaceae).** This species was collected on 10 May 1978 as "indet." and identified later with the help of Cloyce Hedge of the Indiana Natural Heritage Program. Thousands of individuals were found early in the survey in very shallow soil on exposed, flat rock and in the gravel pavement of glade-like areas. A 7 April 1994 census yielded about 780 individuals concentrated in seven open meadow sites. These sites will eventually disappear without management. Introduced fescue is building sod over the few remaining exposed rock sites. *Lespedeza stipulacea* Maxim is well established and Japanese honeysuckle is prevalent and spreading throughout most of the survey area. Although suitable sites occur nearby, the IAAP proposed lease area is the only location in Indiana where this tiny winter annual has been found.

***Spiranthes magnicamporum* Sheviak, Great Plains Ladies' Tresses (Orchidaceae).** A colony of eleven plants was discovered by Homoya (1986) in 1985 growing in the east cedar limestone glade of the IAAP. Its identity was confirmed by Sheviak (1973), and the voucher (*Homoya & Maxwell IND 132295*, 10 October 1985) is deposited at IND. A later search increased the population to about seventeen plants in the southernmost part of the east glade. In 1986, twenty-three plants were found, but they were still confined to the east glade. Observations were sporadic until 1991, when nineteen individuals were counted in the east glade and about thirty-four in the west glade. A west glade voucher (*Maxwell 2838* (IND)) was sent to Sheviak (New York State Museum Herbarium in Albany, New York), and he confirmed that *S. magnicamporum* had appeared in the west glade. A 28 October 1993 search found seventeen plants in the east glade and forty-seven in the west glade. Further study is needed to determine whether the variation among new individuals represents natural development of *S. magnicamporum* or old field and prairie races of *S. cernua* (Sheviak, 1982). Homoya (1993) reports the IAAP glade location in Clark County as the most xeric of the two Indiana locations. The other site is a dune and swale area bordering Lake Michigan in Lake County. The nearest known population of *Spiranthes magnicamporum* is in the Kentucky TNC Pine Creek Barrens Preserve in Bullitt County, Kentucky, about 30 miles due south of the IAAP glades. Maxwell's 20 October 1994 IAAP glades' survey found 41 individuals. On 23 October 1994, he recorded 58 at the Pine Creek Barrens Kentucky site with morphological variations similar to those found in the Indiana populations.

INDIANA THREATENED SPECIES WITHIN THE PARK SITES

***Acalypha deamii* (Weatherby) Ahles., Mercury or Two-seeded Mercury (Euphorbiaceae).** A few plants were discovered by Homoya (with Maxwell) in the Jenny Lind Run ravine area west of the lake in the IAAP proper. A few more were also found in the narrow Fourteen Mile Creek bottom across from Rose Island in the lease area (*Maxwell and Homoya 3052,* 3 October 1994).

***Asplenium ruta-muraria* L., Wall-rue Spleenwort (Aspleniaceae).** A group of about fifteen individuals was found on limestone rock by Homoya. This upper, south-facing ledge line along Lick Creek in the lease area is an open, rocky woods habitat. The species was vouchered by Homoya (with Maxwell and Lewis Johnson) on 29 June 1994.

***Heliotropium tenellum* (Nutt.) Torr., Slender Heliotrope (Boraginaceae).** In August 1981, Medley identified the species as a new State record during a visit to a Harrison County limestone glade (Aldrich, *et al.,* 1981). The same species had been collected by Maxwell in the IAAP glades (*Maxwell 1691,* 20 July 1979) but misidentified. This heliotrope is common in the IAAP glades but very rare in other nearby IAAP glade-like areas.

***Iresine rhizomatosa* Standley, Eastern Bloodleaf (Amaranthaceae).** Homoya pointed out this species in the lease area associated with *Acalphya deamii* (see above). Bloodleaf was occasional at this locality. A voucher (*Maxwell & Homoya 3056A,* 3 October 1994) verifies the Clark County report in Deam (1940).

***Melica nitens* Nutt., Three-flowered Melic Grass (Poaceae).** A few individuals were discovered by Homoya just off the Devil's Backbone in the park area. This species was vouchered by Homoya (with Abrell, Maxwell, and Moberley) on 21 July 1994.

***Sedum telephioides* Michx., Allegheny Stonecrop or Wild Live Forever (Crassulaceae).** In 1984, Jim Aldrich of the Indiana Natural Heritage Program suggested looking for this plant on the upper southeast-facing bluffs of the Ohio River in the IAAP. A few individuals were found south of the lease area in the IAAP in July 1985. Larger populations were discovered later in 1985 within the lease area in the blooming period of September through October. On 3 October 1994, Homoya (with Maxwell) discovered many individuals on the upper southeast-facing bluffs from Battle Creek north to River Ridge in the IAAP proper and south of the lease area. The larger colonies within the lease area have disappeared within the last few years as sun exposure space on the upper rock ledges decreased. Japanese honeysuckle has climbed over the ledges and down into the trapped organic debris on the cliff faces. Only one individual was found on the Devil's Backbone, but other sites nearby seem to exclude the possibility of imminent extirpation in the IAAP.

***Sullivantii sullivantii* (T. & G.) Britton, Sullivantia (Saxifragaceae).** This species is found on the west side of the Devil's Backbone on shaded limestone outcrops on steep slopes above Fourteen Mile Creek. The best of five local outcrop sites was reexamined by Abrell, Homoya, Maxwell, and Moberley on 21 July 1994. Hundreds of plants are flourishing in this remote but very fragile habitat.

INDIANA RARE SPECIES WITHIN THE PARK SITES

***Carex eburnea* F. Boott., Ebony Sedge (Cyperaceae).** This species was pointed out by Homoya on Ohio River cliff faces south of the lease area in the IAAP about 1985. *Carex eburnea* is common and profuse with *Sullivantia* in the park area and was collected (*Maxwell 2048*) on 31 May 1984. The species is occasional to rare in moist, cliff-face limestone pockets in the IAAP.

***Matelea obliqua* (Jacq.) Woodson, (*Gonolobus obliquus* (Jacq.) Schultes (Fernald, 1950)), Angle-Pod (Asclepiadaceae).** This species was collected by Maxwell (*Maxwell 1683*) on 11 June 1979 and determined by Lewis Johnson on 23 September 1994. The collection was from a rocky, open-wooded, south-facing slope of Lick Creek. Common angle-pod, *M. gonocarpa* (Walter) Shinners (*Gonolobus gonocarpus* (Walter) Perry (Fernald, 1950)) is occasional in the IAAP.

***Hexalectris spicata* (Walter) Barnhart, Crested Coral Root Orchid (Orchidaceae).** Two colonies and a single stalk were found under red cedars next to the glades (*Maxwell 1838*) on 6 August 1980. Since then, the species has appeared annually with the number of individuals fluctuating greatly and seldom in the same locations. Only one individual has been found in a glade proper about 1 meter from the wood's margin. Most individuals appear under red cedars at the margins of the existing glades or what were probably former glade margin remnants in the surrounding open, rocky woods.

***Linum sulcatum* Riddell, Grooved Yellow Flax (Linaceae).** This species is found occasionally in the glades.

***Ophioglossum engelmannii* Prantl, Limestone Adder's-Tongue (Ophioglossaceae).** One population was found in the west glade. Hundreds of fronds may appear in May, but very few sporophylls develop.

***Passiflora incarnata* L., Passion-Flower, Maypops (Passifloraceae).** Maxwell's only "IAAP" collection is from a blackberry thicket in an open meadow north of the park area. Homoya and Maxwell observed numerous plants along the power line right-of-way south of River Ridge in the IAAP proper on 3 October 1994. The species was common in vacant lots in Jeffersonville near Warder Park during the 1970s. Recent student collections show it moving from urban environs north into country fence rows.

***Polypodium polypodioides* (L.) Watt., Resurrection Fern (Polypodiaceae).** One individual was seen on the Devil's Backbone on a dry cliff facing the Ohio River (*Maxwell & McKay 2441*) on 3 June 1986.

***Scutellaria parvula* Michx. var. *australis* Fassett, Southern Scullcap (Lamiaceae).** This species is common in the glades and frequently is found in dry gravelly or rocky areas in the survey region. The species is fairly common in similar habitats outside the IAAP in Floyd and Harrison Counties.

CONCLUSIONS

Hopefully, scientific and educational work will continue in the IAAP survey areas with the cooperation of the Division of Natural Resources as it has in the past with the U.S. Army and ICI Americas, Inc. The authors will continue to lobby for the preservation and protection of unique areas within the proposed park, but they also hope that some carefully monitored botanical projects will be acceptable within the final management plan.

Although many IAAP collections are at JEF as "indet.", the critical vascular plant species with their unique habitats have been identified within the park and proposed park areas. Sporadic reports on the survey were sent to the U.S. Army prior to the issuance of Maxwell's annual pass. The preliminary results of the survey (mimeo) will be distributed to the DNR, Divisions of Parks and Nature Preserves, the IND and JEF herbaria, the federal liaison security officer at IAAP, and the Natural Resources Engineer of ICI Americas, Inc., also at IAAP. Hopefully, the faculty and students of Indiana University Southeast will continue their interest in the natural history of the park and will contribute to its success.

ACKNOWLEDGMENTS

The authors wish to thank Dr. David W. Taylor, Director and Curator of the JEF herbarium, for his cooperation and the use of the herbarium's facilities; and Lewis Johnson, Curator (IND), for help with the determinations and discussions regarding Deam and the Deam collections. We also thank the Department of the Army for permission to enter restricted areas. We are also grateful to ICI Americas' security personnel, who have patiently helped over the years by getting us to and from the sampling sites and who have shared their knowledge of the area. Special thanks to Jerry Wiseman, federal security liaison, for allowing access during this transition period. Obviously, continuous encouragement and shared knowledge from individuals within the DNR, Indiana Division of Nature Preserves, over the years provided the impetus for most of our local flora work. These individuals include Cloyce Hedge and James Aldrich, Indiana Natural Heritage Program Directors, and, particularly, Michael A. Homoya, Nature Preserves Botanist, and John Bacone, Director of the Division of Nature Preserves. Thanks also go to Mr. Gerald J. Pagac, Director of the Division of State Parks, for providing us with a 1994 collecting permit for the park area and responding graciously and constructively to those whose help was solicited for preservation of the Little Bluestem Cedar Limestone glades within the lease park area.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 233-239

YOU ARE WHAT YOU THINK: THE PERPETUATING NATURE OF SELF-ESTEEM

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ABSTRACT: Residents at a shelter for battered women and children were given the Rosenberg self-esteem scale and a 25-item abuse history questionnaire upon entrance to the shelter. During the resident's 30-day stay at the shelter, measures of acceptance of offered guidance/counseling services were also collected, and a measure of exit outcome was given just prior to the resident's leaving the shelter. A higher score on the exit outcome test indicated that the resident chose an exit outcome that moved her back toward the abusive relationship. Correlations between self-esteem, magnitude of abuse history, guidance/counseling services accepted, and exit outcome as well as *t*-test analyses comparing self-esteem (computed categorically as high or low) to exit outcome were computed. As predicted, initial self-esteem levels significantly predicted exit outcome. Those residents with lower self-esteem levels upon entrance to the shelter were most likely to return to the abusive relationship, while those with higher entrance self-esteem levels were likely to exit by moving away from that relationship. The correlations suggest the existence of some compelling relationships between the variables and abusive relationships.

KEYWORDS: Abuse shelters, battered women, crisis intervention, cycles of abuse, family violence, self-esteem.

INTRODUCTION

Every individual has encountered someone who suffers from low self-esteem. Many of these same individuals have also expended a great deal of time and effort trying to "help" that person recover from their negative feelings of self-worth. But, as anyone who has ever tried to enhance the self-esteem of someone else can tell you, the task is difficult at best. It seems that everyone should want to feel better about themselves and, as such, should welcome positive feedback from others with open arms. Although at some level this is true (e.g., Snyder and Higgins, 1988; Brown, *et al.,* 1988; Tesser, 1988), individuals suffering from low self-esteem may have as many good reasons to resist positive information as they do to seek it out or accept it (Tice, 1993). Before moving on to illustrate how individuals with low self-esteem may perpetuate their own misery (by engaging in interpretive patterns that specifically reinforce their negative self-views), further time should be spent explaining why low self-esteem individuals may work very hard to avoid positive feedback.

Why and when will low self-esteem persons resist positive feedback? Low self-esteem persons have been characterized as having a self-defeating attitude that can perpetuate the feelings of low self-esteem (Brockner, 1983). Although this concept seems to make perfect sense, some individuals may feel that it is so counter intuitive as to have little or no heuristic value. The thought of a negative self-esteem loop perpetuating the misery of the individual with low self-esteem is certainly not something pleasant to consider. Recent lines of research, however, do converge on this perpetuating cycle and the implications that such a cycle would have for the self of the individual in question and the behavioral choices that the individual will make (Spencer, *et al.,* 1993; Osborne and Stites, work in progress).

Individuals with low self-esteem have been shown to be less certain about which self-related characteristics describe them (Baumgardner, 1990), to get bound up in thinking about what they should be like rather than what they are like (McKay and Fanning, 1987), to prefer negative feedback over positive because it supports feelings of control and predictability of self (Lecky, 1945; Swann, *et al.,* 1992), to have different self-related motives than individuals with high self-esteem (Tice, 1991, 1993), and to lack positive self-views that would otherwise allow for self-esteem to be enhanced (Blaine and Crocker, 1993).

Psychologists have long known that individuals need to feel that their social environments are controlled and predictable. This need for predictability in social interaction was noted by Simon (1990) as one of the few invariants in human information processing and interaction. This need for consistency and predictability, however, also suggests that individuals with low self-esteem may find positive feedback particularly distressing. Positive information can be perceived by individuals with low self-esteem as posing a direct threat to self-consistency and predictability.

Self-motives may play a role in the perpetuating nature of self-esteem as well. Because the first goals of individuals with low self-esteem in social situations are to avoid embarrassment, humiliation, failure, or rejection (Tice, 1991), they do not approach these situations with the same motives as individuals with high self-esteem. Since the goal is to avoid negative consequences, the low self-esteem individual may find positive feedback to be particularly stressful, because it may place even greater demands on them for future performance (Tice, 1993). Individuals also have a strong emotional investment in the conceptions they hold of their selves (Greenwald, 1980). Because of these emotional investments, the individual rarely will reject those prior self-conceptions in the face of newly acquired discrepant self-related feedback.

Low self-esteem and high self-esteem individuals may also choose the same self-motive for entirely different reasons. One such motive is called self-handicapping (Berglas, 1988; Berglas and Jones, 1978). When utilizing self-handicapping, the individual may initiate actions to sabotage his or her own performance (or at least make success much less likely) in order to create ready made excuses for anticipated failure (Berglas and Jones, 1978). An individual may make situational success seem even less likely by either not practicing a difficult task or by bemoaning how sick they feel or how tired they are prior to some type of situational performance. Then, if they perform poorly in the situation, the lack of practice or ill health may be blamed. If the individual succeeds despite the adversity, he or she can take even greater credit for the success.

Low self-esteem sufferers may consider esteem to be an extremely limited resource that they are not willing to risk even if positive self-feelings could be the payoff (Osborne, 1993a, 1993c; Pelham, 1991, 1993). Blaine and Crocker (1993) suggested that persons with high self-esteem tend to engage in self-serving attributions (thereby attributing situational events and feedback in such a way as to bolster feelings of self-worth). These same researchers, however, also found that persons with low self-esteem will either not use self-serving biases or may even choose to self-deprecate (thereby maintaining negative self-feelings even in the face of positive feedback). Osborne and Stites (work in progress) suggest that the degree of self-negativity may be the deciding factor in determining whether the individual will self-deprecate.

This summary of the implications and ramifications of low self-esteem may help one to understand the tug-of-war that the low self-esteem person may be experiencing with his or her own self. According to Brown (1993), low self-esteem individuals face a unique bind because they have two mutually incompatible motivational needs. On the one hand, the individual is motivated to acquire positive information about self and, therefore, self-enhance. At the same time, however, this individual is motivated to maintain self-consistency. In this fashion, the low self-esteem individual is placed in a particularly dangerous crossfire from which the safest path of escape may simply be to maintain the self-esteem status quo (De La Ronde and Swann, 1993).

How does low self-esteem perpetuate itself? The manner by which individuals interpret their successes and failures plays a pivotal role in determining future actions (Seligman, 1975; Weiner, 1986). In his original model of learned helplessness, Seligman (1975) suggested that depression could result from exposure to uncontrollable outcomes. In a sophisticated reformulation of this model, Abramson, *et al.* (1978) concluded that it was not just the level of controllability for the event that determined depression but also the attributions the individual made for such events. At least three types of attributions are likely: internal versus external, global versus specific, and stable versus specific. In this reformulation, individuals who make stable, global, and internal attributions for an uncontrollable event are likely to experience a depressive reaction.

Numerous studies on depression show what has come to be known as a "depressive explanatory style" (Peterson and Seligman, 1987), and this explanatory style has recently been applied to the manner in which low self-esteem sufferers interpret feedback as well. Even in situations where feedback about the controllability of the event is ambiguous, some persons seem to "choose" to explain the event in a fashion that makes them feel bad. Low self-esteem persons have been shown to actively interpret events in a fashion that perpetuates low self-esteem (Osborne and Stites, work in progress; Tennen, *et al.*, 1987). Osborne and Stites (work in progress) found that low self-esteem persons interpret their failures so as to allow them to blame themselves for those failures, and they suggested that such interpretive patterns may determine the future self-related actions of those persons.

Based on the model of Abramson, *et al.* (1978) and information about the motives and goals that seem to motivate individuals with low self-esteem, Osborne (1993a-c) suggested that individuals may interpret self-related feedback on three levels: 1) internal versus external; 2) temporary versus stable; and 3) global versus specific. The manner in which self-related feedback is interpreted can directly influence the impact such feedback will have on self-esteem (Osborne, 1993a-c).

Osborne and Stites (work in progress) provided self-related situational scenarios to subjects with high and low self-esteem. First, the subjects were administered self-esteem questionnaires. Then, they were asked to read multiple situational scenarios and were instructed to choose from a list of options for each scenario the option that most closely matched why they thought such as event might happen to them (these items were based on the Attributional Style Questionnaire of Peterson and Seligman, 1987). As predicted, subjects with low self-esteem chose explanatory options that labeled positive self-related events or successes as due to external, temporary, and specific causes. At the same time, these low self-esteem persons chose internal, stable, and global explanatory options for negative self-related events or failures.

By making differential interpretations for successes and failures, the low self-esteem sufferer perpetuates his/her misery by guaranteeing that positive feedback will be minimized while negative feedback will be maximized. High self-esteem subjects showed the opposite pattern. Individuals with high self-esteem interpreted positive self-related events or successes in a fashion that allowed them to take credit for those successes while rejecting blame for failures by making external, temporary, and specific interpretations for negative self-related events.

Numerous studies have found a relationship between self-esteem and perceptions of the cause of domestic violence (Cannon and Sparks, 1989; Schutte, *et al.*, 1986). Little clear evidence exists, however, on the relationship between self-esteem levels upon entering the shelter and the abused person's decision to return to the abusive relationship. Although Schutte, *et al.* (1986) found that only 4 out of 48 women in their shelter sample planned to go back to the abusive relationship, a very different pattern might emerge if measures are taken of the actual (rather than the planned) outcome.

MATERIALS AND METHODS

In this study, the procedure of Osborne and Stites (work in progress) was extended to an applied setting and tracked true outcome upon leaving the shelter rather than just planned outcome. Residents of an abuse shelter were given self-esteem scales, an abuse history questionnaire, and varying levels of on-site guidance and counseling; then, upon departing the shelter, outcome data were collected. Outcomes were scored to reflect the degree to which the outcome moved the resident back into or away from the abusive relationship. By tracking the true outcome, it became possible to determine whether or not prior abuse history, entrance self-esteem levels, or levels of on-site guidance and counseling most significantly predicted outcome upon leaving the shelter. (The levels of guidance/counseling sought by shelter residents were on a volunteer basis and could be confounded with both entrance self-esteem levels and prior abuse history.)

Given the role self-esteem has been shown to play in both interpretations for events (Abramson, *et al.*, 1978; Osborne and Stites, work in progress) and in future behavioral choices (Swann, *et al.*, 1992), the author predicted that those residents with lower self-esteem scores would be more likely to exhibit shelter exit outcomes that moved them back toward the abusive relationship. In this case, self-esteem scores were recoded as either high or low and then used as a categorical variable in *t*-test analyses of the subjects' outcome scores. Correlations were also computed between entrance self-esteem levels, prior abuse history, levels of guidance/counseling, and shelter exit outcome.

Table 1. Correlation between the four variables examined in this study.

	Self-Esteem	Abuse History	Guidance/ Counseling	Exit Outcome
Self-esteem	1.000			
Abuse history	- 0.179	1.000		
Guidance/Counseling	- 0.061	0.486	1.000	
Exit outcome	- 0.830	0.223	0.369	1.000

RESULTS

A paired *t*-test was run to study the relationship between self-esteem and exit outcome. Self-esteem level strongly predicted abuse history outcome ($\bar{X} = -2.25$; $t_{(1,19)} = -10.411$; $p < 0.0001$). Those shelter residents with higher self-esteem were more likely than their lower self-esteem counterparts to choose outcomes that moved them away from the abusive relationship. Persons with lower self-esteem chose outcomes that moved them back toward the abusive relationship.

The correlation matrix between self-esteem entrance levels, prior abuse history scores, levels of guidance/counseling accepted, and shelter exit outcome, conforms to prediction as well (Table 1). The highest correlation obtained was between entrance self-esteem levels and exit outcome. The negative correlation signals that the higher the entrance self-esteem level, the less likely the residents were to exit the shelter in a manner that moved them back toward the abusive relationship.

Levels of guidance/counseling accepted while a resident at the shelter also correlated significantly with magnitude of abuse history (Table 1). In this case, the positive correlation indicates that the greater the magnitude of abuse history, the greater the seeking of offered guidance/counseling. One potentially troublesome aspect of the correlational findings, however, was the marginally significant correlation between levels of guidance/counseling accepted and exit outcome. The modest positive correlation between these two variables (Table 1) suggests a relationship between levels of guidance/counseling sought and more negative exit outcomes. Certainly nothing in this data suggests a causal link between these two variables, but the suggested relationship between them merits further study.

DISCUSSION

These findings support Osborne and Stites' (work in progress) suggestion that self-esteem level will influence the future actions of an individual. The role that self-esteem may play in the manner by which individuals interpret abuse and in the abuse outcome choices individuals will make is of crucial importance. Further research needs to address the potential impact of self-esteem enhancement programs on outcome choices of battered shelter residents. If self-esteem plays such a crucial role in determining whether the abuse victim will migrate back toward or away from the abusive relationship following residency at a shelter, the role that self-esteem enhancement strategies might play in helping such victims make better exit choices must be assessed.

Although discussing abuse is in no way a pleasant experience, the importance of such conversations cannot be overstated. Questions about why individuals with low self-esteem may migrate back toward abusive relationships are really not that difficult to answer. First, remember that self-uncertainty is considered to be much more uncomfortable than self-certainty. This fact, in conjunction with an awareness that many abusive relationships are predicated on the efforts of the abuser to maintain control over the abused, makes the situation even more powerful. Once low self-esteem is in place, even if it comes about because of abuse, it tends to perpetuate itself in the fashion described earlier. Since the abuse victim may actually believe that he or she deserves no better, attempts by others to enhance their self-esteem will be met with little initial success.

Once the individual's time at the shelter is over (bear in mind that most shelters allow residents to stay a maximum of 30 days), what other choice would the victim see him- or herself capable or worthy of making? Because the victim's self-definition is so wrapped up with that of the abuser, the less threatening exit outcome, in terms of potential impact on self, is to migrate back to the relationship. Although the abuse victim does not covet the abuse, he or she may covet a lack of self definition and/or self-uncertainty even less.

ACKNOWLEDGMENTS

The author thanks the Genesis Shelter for their support of this data collection. Special thanks go to Diane Osborne for her help with the preparation and editing of this manuscript and to Brandy Finfrock, Lonel Fisher-Stites, James and Penny Penticuff, Susan Waters, and Ken Weadick for their helpful thoughts about this line of research.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 241-247

DETERMINATION OF CYANIDE IN SOILS AND WASTES BY ION CHROMATOGRAPHY

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ABSTRACT: Ion chromatography was evaluated for its ability to measure free cyanide (CN) in environmental samples. Liquid and soil samples as well as composted sewage sludge were treated with known amounts of CN as KCN. Samples were digested and analyzed for CN using EPA Method 9010 and ion chromatography. Ion chromatography proved to be advantageous over Method 9010 due to more rapid sample analysis with greater or equal accuracy. Furthermore, the detection ranges were greatly expanded when the Method 9010 colorimetric procedure of quantification was replaced with ion chromatography. When the Method 9010 distillation procedure was combined with ion chromatographic quantification, CN results were favorable for both aqueous and solid samples. The detection range increased by 92%, and 1.5 hours were saved with the new procedure. Ion chromatography holds promise for improving CN analysis as well as for increasing the spectrum of samples which can be analyzed.

KEYWORDS: Cyanide, ion chromatography, soil, and solid waste.

INTRODUCTION

Cyanide (CN) may occur in soils and water as a result of improper disposal of CN-containing industrial wastes (Brooks, 1992; DeBell, *et al.*, 1982; Galceran, *et al.*, 1990; Martin, 1992). In addition, naturally occurring CN is produced as a result of microbial activity (Kunz, *et al.*, 1992). The detection and quantitative determination of CN in soils is integral to the proper assessment and ultimate remediation of contaminated media due its potential impacts on public health and the environment.

Currently existing techniques for CN determination are inadequate in terms of the range of concentrations that can be detected as well as in terms of the types of samples that can be analyzed. The currently accepted EPA method for CN detection, Standard Method 9010 (U.S. Environmental Protection Agency, 1986), is used to determine CN concentration in aqueous wastes and leachate. The method involves rigorous sample distillation in an acidic environment, liberation of HCN gas, HCN collection in an alkaline absorbing solution, and measurement of CN concentration via colorimetric analysis of a cyanide-chloramine-pyridine complex. The detection range is limited to 0.01-0.4 μg/mL CN, a range which is impractical when considering the concentrations of CN that may occur in soils as a result of the introduction of industrial wastes (Martin, 1992). The U.S. Environmental Protection Agency (1992) considers a soil "heavily contaminated" with CN in the 100-500 mg/kg range.

A number of methods for CN analysis currently exist (Blanco and Maspoch, 1984; Dionex, 1986; Ingersoll, *et al.*, 1981; Meeussen, 1992; Okuno, *et al.*, 1979;

Table 1. Selected properties of soils and waste samples.

Material	Classification	TOC[1] (%)	Cd	Cu	Fe	Zn	pH	EC[2] (dS/m)
					µg/g			
Glynwood topsoil	Fine, illitic, mesic, Aquic Hapludalf	1.00	0.005	0.02	9.05	1.55	6.7	0.315
Glynwood subsoil		0.99	0.005	0.02	13.80	0.005	6.6	0.313
Pemberton	Loamy, mixed, mesic Arenic Hapludults	1.05	0.005	0.01	3.86	7.50	6.7	0.422
Composted sewage sludge		30.5	0.015	0.02	53.25	3.90	4.8	11.56

[1] TOC = Total organic carbon.

[2] EC = Electrical conductivity.

Owerbach, 1985). Ingersoll, *et al.* (1981) outlined a three-step process for analyzing samples containing metal-CN complexes: 1) dissociation of the complexes using competing ligands; 2) distillation; and 3) quantification of CN using an ion selective electrode. Meeussen (1992) described an automated method for CN determination using UV irradiation to decompose metal-CN complexes followed by distillation of the sample and then by spectrophotometric analysis. Okuno, *et al.* (1979) outlined procedures for CN analysis using gas chromatography. Although the above methods are successful in the measurement of CN, these methods are specific for aqueous samples only. Few methods exist for CN determination in soils, and less information is available on CN measurement in solid wastes. A method using distillation and differential pulsed polarography has been developed for soil analysis (Adeloju and Gawne, 1986). A major drawback of their method, however, is the distillation time needed to achieve acceptable recovery rates — up to four hours is required for soil samples. A microdiffusion procedure developed by Dartnall and Burns (1987) realized CN recovery rates of only 60% from soils.

The colorimetric analysis for CN detection outlined in Method 9010, in addition to having a restrictive detection range, is a time-consuming procedure. Furthermore, the cyanide-chloramine-pyridine complex is susceptible to rapid color loss and must be handled as a hazardous waste. Ion chromatography (IC) may serve as a possible replacement for colorimetric analysis. In 1983, the Dionex Corporation developed a method for CN detection via IC. The method provides for accurate, reproducible determinations of CN in aqueous samples without relying on time-dependent color formation reactions. In addition, the generation of hazardous by-products is minimized.

The purpose of the reported research was to develop a technique for CN quantification in soils and wastes employing detection by ion chromatography. Specifically, the objectives were: to 1) develop a more efficient method for determination of CN in aqueous samples; to 2) expand the range of CN

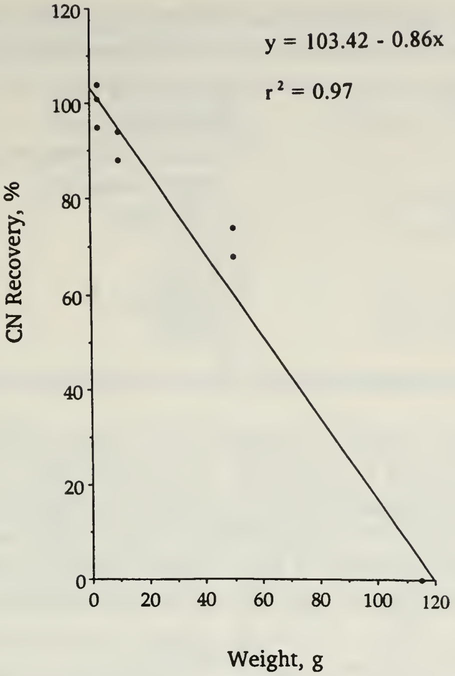

Figure 1. Percent CN recovery from Glynwood soil as a function of initial soil weight.

concentrations which could be detected using IC; and to 3) expand the range of samples that could be analyzed with the Method 9010 distillation process combined with IC to include soils and solid wastes.

MATERIALS AND METHODS

Samples of Glynwood and Pemberton soils were collected from agricultural fields in a corn-soybean rotation (Table 1). Subsoil material was collected from 50 to 75 cm below the surface. Composted sewage sludge was collected at the Southwesterly Compost Facility, Columbus, Ohio. The soil and waste samples were collected with a sampling tube, composited, and brought to the laboratory, where they were air-dried, crushed, and sieved to pass a 2-mm sieve.

The concentrations of Cd, Cu, and Zn were obtained from dilute HCl extracts (Nelson, *et al.*, 1959). A 2.0 g sample of soil was added to 20 mL of 0.1 N HCl and centrifuged for 5 minutes. The clear supernatant was then analyzed by atomic absorption spectroscopy (AAS). Fe determination was performed as described by Olson and Ellis (1982). A 10 g sample of soil was extracted using a solution of 0.005 M DTPA, 0.1 M TEA, and 0.01 M $CaCl_2$ (pH 7.3). The resulting mixture was shaken at 180 opm for 2 hours. After shaking, the samples were filtered through Whatman No. 42 filter paper and analyzed via AAS. Total organic carbon concentration was analyzed using a Dohrmann Carbon analyzer; pH was measured on a 1:1 solids:water sample using a Fisher pH meter. Electrical conductivity was measured on a 1:1 extract using a YSI conductivity meter.

Table 2. Operating conditions for ion chromatographic determination of CN.

Separator column	Dionex HPIC-AS7
Guard column	Dionex HPIC-AG7
Eluant	0.5 M CH_3CO_2Na, 0.1 M NaOH, 0.5 % ethylenediamine
Eluant flow rate	0.9 mL/min
Injection loop	200 µL
Output voltage	0-1 Volts
Output range	300-300 nA
Pressure	1400 psi
Electrode	Ag

CN Treatments. Aqueous samples were spiked with CN solutions ranging in concentration from 0.1 to 1.0 µg/mL. CN was added as KCN in H_2O adjusted to pH 9.0. Soil and composted sludge samples were treated with the pH 9.0 KCN solution as well. Final CN concentrations in the solids was 10 µg CN/g solids.

Colorimetric Procedure. Liquid samples analyzed for CN were distilled according to the procedure outlined as Method 9010 (U.S. Environmental Protection Agency, 1986). A 500-mL sample was placed in a 1 L boiling flask and 5 mL of 1.25 N NaOH was added. Through the air inlet tube, a slow stream of air was introduced so that approximately 3 bubbles per second appeared in the solution in the boiling flask. Lead acetate paper was used to check the samples for sulfides. A 50 mL sulfamic acid solution was added, if samples were suspected to contain NO_2 or NO_3. After allowing the solution to mix for three minutes, 50 mL of 1:1 H_2SO_4 followed by 20 mL of $MgCl_2$ were added through the air inlet tube. The solution was heated to boiling and refluxed for 1 hour. Fifty mL of the alkaline-absorbing solution was withdrawn and mixed with 15 mL of 1 M NaH_2PO_4 and 2 mL of chloramine-T. A 5 mL pyridine barbituric acid solution was added next. Absorbance was read at 578 nm in a 1-cm cell within 15 minutes.

Ion Chromatography Procedure. The ion chromatograph (IC) used was a Dionex Model 2000-i instrument with a pulsed amperometric detector (Dionex

Table 3. A comparison of Method 9010 and ion chromatography for CN determination in aqueous samples with and without distillation.

	Actual	Method 9010	IC
	µg/ml		
Not distilled	0.1	0.09 ± 0.04	0.10 ± 0.008
	0.5	0.54 ± 0.06	0.55 ± 0.009
	1.0	1.02 ± 0.07	1.13 ± 0.01
Distilled	0.1	0.07 ± 0.01	0.1 ± 0.005
	0.5	0.49 ± 0.03	0.5 ± 0.01
	1.0	1.00 ± 0.03	1.0 ± 0.01

Table 4. A comparison of the percent recovery of CN from 2.5 g of composted sewage sludge with and without EDTA.

Method	Ligand	CN Recovery (%)
9010	—	36 ± 0.02
IC	—	75 ± 0.07*
9010	EDTA	61 ± 0.08
IC	EDTA	100 ± 0.05*

* Significant at the $\alpha = 0.05$ level.

Corp., Sunnyvale, California; Table 2). An eluant containing 0.5 M sodium acetate, 0.1 M NaOH, and 0.5% ethylenediamine (Pohlandt-Watson, 1986) was used for CN detection. The concentration of CN present in the samples was recorded by measurement of peak heights obtained with a Dionex 4270 Integrator.

RESULTS

Aqueous samples were analyzed for CN content both before and after distillation to determine if boiling and subsequent CN recovery in the alkali trap solution would affect overall recovery. The CN recovery rates both in distilled and undistilled aqueous samples were similar for IC and colorimetric determinations (Table 3). CN determinations using ion chromatographic analysis, however, showed a higher degree of accuracy and lower standard deviations than those of colorimetric analysis.

Soil and Sludge Analysis. The Method 9010 distillation procedure was applied to the soils and sludge listed in Table 1, following which all materials were analyzed colorimetrically as well as via IC. Method 9010 is designed for aqueous sample analysis only. Therefore, the method was modified for the digestion of solids. Originally, 115 g of CN-treated soil or sludge was added to the distillation flask. Due to bumping, plugging of the air inlet tube, and foaming of the soil-CN mixture, 115 g soil was too much to allow for complete distillation. The amount of soil distilled also had a negative relationship with the amount of CN recovered (Figure 1). Large amounts of soil may have allowed excessive metal-CN complexation. A soil weight of 2.5 g was found to be satisfactory for proper digestion and subsequent CN measurement.

The soils and sludge were evaluated for content of metals and total organic carbon (TOC) to determine the relationship between metal and TOC content and % CN recovery. The % CN recovery obtained from distilling 2.5 g of sample ranged from 98% to 100% for the soils (data not tabulated) but was only 75% for the sludge (Table 4). Recovery using IC was significantly higher (as indicated by the *t*-test) than recovery via Method 9010. The sludge had the highest concentrations of Cd and Fe (0.015 and 53.25 μg/g, respectively) compared to the other samples. Furthermore, the sludge had an EC which was 27 times that of the nearest soil sample, the Pemberton. Such solute concentrations increase the

Table 5. Regression equations and coefficients of determination (R^2) for soil TOC and metals and CN recovery by ion chromatography.

	Equation	R^2
TOC	$Y = 73.36 \times 10^{(-6.04e-3X)}$	0.62 n.s.*
Cd	$Y = 88.78 \times 10^{(-17.18X)}$	0.61 n.s.
Cu	$Y = 533.33X + 57.67$	0.02 n.s.
Fe	$Y = 77.78 \times 10^{(-3.81e-3X)}$	0.57 n.s.
Zn	$Y = -2.57X + 74.72$	0.17 n.s.

* Not significant.

probability of CN complexation. Several CN complexes are very difficult to dissociate prior to detection (Ingersoll, *et al.,* 1981). To obtain higher CN recovery rates with the sludge, 0.1 g of ethylenediamine tetraacetic acid (EDTA) was added to the distillation vessel. EDTA complexes with metals, thus inhibiting the metals from reacting with CN. Distillation with the addition of EDTA provided for 100% CN recovery from the sludge (Table 4). Regression analysis revealed that TOC, Cd, Cu, Fe, and Zn concentrations were correlated, though not significantly, with CN recovery from the soil and sludge samples (Table 5).

The colorimetric results for CN in soil and sludge were considerably lower than those measured with IC (Table 4). Since the colorimetric test was designed for aqueous samples only, the soils and sludges may introduce impurities (e.g., organic compounds) that interfere with the CN-pyridine-chloramine color complex. The IC results were consistent and reproducible for both soil and sludge samples. The chromatograms obtained for soil analysis had sharp peaks, indicating a lack of interfering compounds.

The detection range of the IC for CN was from 0.01 to 14 μg/mL, which is a 92% increase in range over that available with the colorimetric procedure. In addition, IC was faster; sample preparation and analysis using the colorimetric procedure took 1.75 h, whereas the IC procedure required only 0.25 h. Furthermore, hazardous waste production is minimized in the IC method, as the pyridine barbituric acid solution (Method 9010) is not used.

CONCLUSIONS

Ion chromatography was found to be a more accurate method of determining CN concentration in aqueous samples as well as a more accurate and consistent method for soil and sludge analysis due to the lack of interference that occurs using colorimetric analysis. The distillation outlined in Method 9010 for aqueous samples containing CN can be used to distill soil and sludge, with 2.5 g of sample yielding optimum results. The addition of EDTA to soils and sludges with high metal content is necessary to eliminate the CN-metal complexes present. Due to expanded detection ranges, rapid sample analysis, greater accuracy, and a lack of hazardous by-products, ion chromatography appears to be superior to Method 9010 for determining the presence of CN.

ACKNOWLEDGMENTS

Financial support from Ball State University and the Indiana Academy of Science is gratefully acknowledged.

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Proceedings of the Indiana Academy of Science
(1995) Volume 104 (3-4) p. 249-258

DISTRIBUTION OF THE MOSQUITOFISH, *GAMBUSIA AFFINIS* (BAIRD & GIRARD), IN INDIANA, WITH COMMENTS ON RESOURCE COMPETITION

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ABSTRACT:The mosquitofish, *Gambusia affinis,* was collected in 14 counties in southern and western Indiana: Daviess*, Dubois*, Gibson, Greene*, Knox, Owen*, Perry, Pike, Posey, Spencer*, Sullivan*, Vanderburgh, Vigo*, and Warrick. Counties marked with an asterisk plus records for Clark and Lake Counties constitute new county records. The species has expanded its range to the north and east in Indiana, reaching southern Vigo County by about 1990. Stomach analysis of 403 individuals indicated that midge adults were the most common food item. Other important foods included algae, *Plumatella* (Bryozoa), Diptera, Corixidae, chironomid larvae, and chironomid pupae. Only 1 mosquito, an adult, was found during the study. The food of the blackstripe topminnow, *Fundulus notatus,* was compared to that of *Gambusia.* The two have similar food habits — their major food is the adult midge.

KEYWORDS: Distribution, food habits, *Gambusia affinis.*

INTRODUCTION

The mosquitofish, *Gambusia affinis,* is a small, surface dwelling fish of the family Poeciliidae and is the only species of livebearer native to Indiana. *Gambusia affinis* is found throughout the southern United States. The mosquitofish occurs in the lower third of the Ohio River Basin (Pearson and Krumholz, 1984), where it is native to Kentucky (Clay, 1975; Burr and Warren, 1987) and southern Illinois (Smith, 1979; Burr and Warren, 1987). The first 3 collections from Indiana were from Posey County in extreme southwestern Indiana (Jordan, 1890). Hubbs and Lagler (1942) found the mosquitofish to be "rare" in Foots Pond, Gibson County. Gerking (1945) collected it in Gibson, Knox, and Perry Counties. *Gambusia affinis* was collected from the White River in Pike County (Proffitt and Benda, 1971), at several locations in the White River between Pike and Knox Counties (T.P. Simon, pers. comm.), and at other sites in and near Posey County (Grannan and Lodato, 1986; Kozel, *et al.,* 1981). Thomas Cervone (pers. comm.) has recently taken the mosquitofish in the tributaries of the White River and Pigeon Creek drainage in Daviess and Gibson Counties as well as in Clark County in 1985. In addition, mosquitofish were taken in 1989 in northwestern Indiana in the Kankakee River in Lake County (T.P. Simon, pers. comm.). The Lake County population may indicate an invasion from Illinois (T.P. Simon, pers. comm.), as Krumholz had previously (1944) documented the existence of the mosquitofish as far north as the Chicago area as a result of both natural and human introductions.

Much interest was generated during the early part of this century on the use of *Gambusia* in mosquito control. To this end, experimental transplants of *Gambusia* were made to the Hawaiian Islands (Jordan, 1926), Utah (Rees, 1934), Illinois (Krumholz, 1944), and Michigan (Hubbs and Lagler, 1958). No record of any transplants in Indiana is known.

Two specimens of *Gambusia* were collected in 1927 by T.R. Becker, supposedly from Vigo County, Indiana, in a flood puddle near the Wabash River (T.P. Simon, pers. comm.). The specimens are in the museum at the University of Michigan, but the record has not been published. Since no mosquitofish were found after considerable sampling during a survey of the fish of Vigo County (Whitaker and Wallace, 1972), the collecting locality of the 1927 specimens may be in error.

Six individuals of *Gambusia affinis* were collected in September 1990 in Negro Ditch in southern Vigo County by the vertebrate zoology class at Indiana State University. This site has been sampled almost yearly since 1964, but no mosquitofish had been taken prior to 1990. Since the species had not previously been taken north of Knox County, this collection stimulated further sampling to determine the present distribution of the fish in Indiana. The present study was also undertaken to examine *Gambusia*'s food habits and to compare its food habits to those of the blackstripe topminnow. The mosquitofish resembles a topminnow in appearance and feeding habits, and Cervone, *et al.* (1989) referred to the topminnow as an ecological equivalent of *Gambusia.* While the mosquitofish has been taken only from southwestern Indiana, the blackstripe topminnow, *Fundulus notatus,* is distributed throughout the State. Do the two species eat similar foods and is there any evidence of food partitioning where they occur together?

MATERIALS AND METHODS

Mosquitofish were previously known only from Posey, Gibson, Knox, Vanderburgh, Pike, Warrick, and Perry Counties in southwestern Indiana. Those counties as well as sites in other counties to the north and east that contained likely habitat (small streams or intermittent ponds with little or no current) were sampled to determine the present distribution of the species.

Most collections were taken using either a 12- and 18-foot, 1/8"-mesh seine, but a hand-held dip net was used at locations where the ditches or streams were very small and mosquitofish were visible near the surface. A total of 71 sites were sampled in 25 counties between 28 September 1991 and 13 July 1992 (Figure 1). One collection in 1991 and all the earlier collections were made using 30-foot, 1/4"-mesh seines.

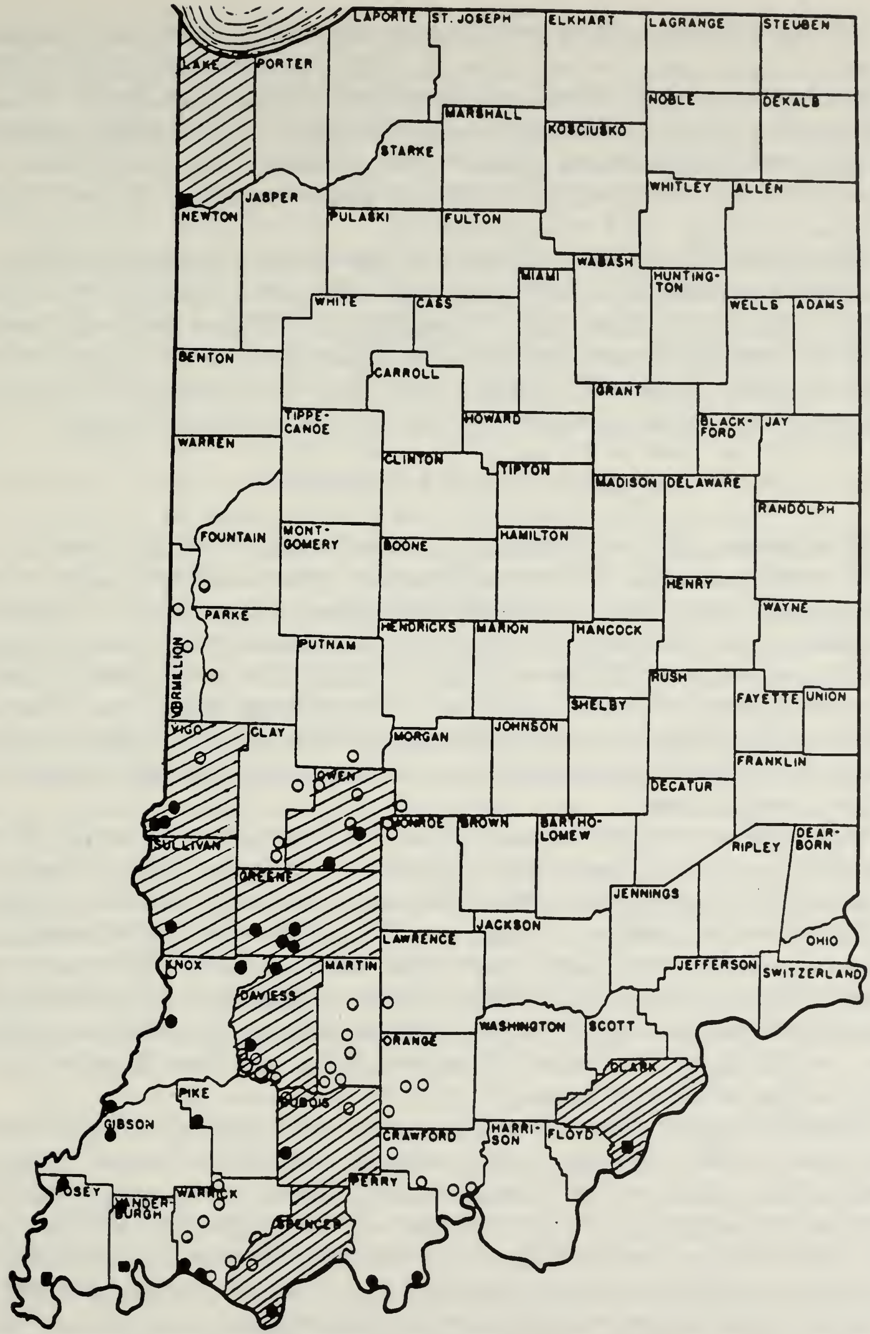

Figure 1. The distribution of the mosquitofish, *Gambusia affinis,* in Indiana. Sampling sites where mosquitofish were collected are indicated by solid (●) circles; sites sampled where no mosquitofish were collected are indicated by hollow (○) circles. Solid squares (■) indicate that populations were present but not sampled by the authors. New county records are indicated by hash marks (///). The Lake County information was provided courtesy of Thomas P. Simon; the Clark County information, courtesy of Thomas H. Cervone.

The fish were preserved in 10% formalin; their stomachs were removed and the contents were placed in petri dishes; then the contents were examined using a dissecting microscope to identify as many food items as possible. Visual estimates were made of the volume of each food item in each stomach, and the data were then summarized as percent volume ([sum of individual volumes of food/total volume of all stomachs] x 100) and percent frequency (the percentage of stomachs in which the food item occurred).

Nine collections of *Gambusia,* taken in 1967 in Posey County, Indiana, and 4 collections of *Fundulus notatus* from Vigo County were examined by similar methods. These data, taken before *Gambusia* had advanced northward, were compared with the current data from the areas where the two species now occur together. Statistical analyses were done by running ANOVA and Student-Newman-Keuls multiple range tests on arcsine transformed data.

RESULTS AND DISCUSSION

Distribution. *Gambusia affinis* was collected from 25 of 71 sites in 14 of the 25 counties sampled in Indiana (Figure 1). Over 1,000 individuals were collected in October 1991 from Negro Ditch, Vigo County, where the first six individuals from the County had been taken the previous year. The species is currently present in Clark*, Daviess*, Dubois*, Gibson, Greene*, Knox, Owen*, Perry, Pike, Posey, Spencer*, Sullivan*, Vanderburgh, Vigo*, and Warrick Counties in the drainages of the Ohio, Patoka, Wabash, and White Rivers as well as in the Kankakee River in Lake* County. (Those counties marked with asterisks are new county records.)

Mosquitofish were taken from streams with bottom features ranging from solid rock, to gravel, sand and sand-gravel, and mud. The presence of mosquitofish in Clark, Daviess, Dubois, Greene, Lake, Owen, Spencer, Sullivan, and Vigo Counties indicates a range extension of the species northward and eastward from its historical range in the State (Gerking, 1945). The presence of mosquitofish in Lake County probably indicates an extension of the species into Indiana from fish introduced into northern Illinois, because the species was absent from samples taken in the counties (Fountain, Parke, and Vermillion Counties) between Vigo and Lake Counties.

When the mosquitofish reached the counties north and east of its historical range is not certain. *Gambusia* was probably absent from Daviess, Dubois, Greene, Owen, Spencer, and Warrick Counties before 1945, as Gerking did extensive sampling in those counties at that time. The progression of the species up the West Fork of the White River and into the headwaters of the Patoka in recent years could be due to agricultural practices that have changed the profile of the rivers and made more suitable habitat for *Gambusia.*

The time when *Gambusia* arrived in Negro Ditch in southern Vigo County is easier to pinpoint. Seine samples have been taken in Oxendine Bayou, Negro Ditch, and the Wabash River in southern Vigo County almost yearly from 1964 to the present by vertebrate zoology classes at Indiana State University. No *Gambusia* was ever found in these collections until September 1990, when 6 individuals were taken in Negro Ditch. During September 1991, large numbers (1000) were collected from Negro Ditch, Oxendine Bayou, and Prairie Creek in southern Vigo County. These data indicate a range extension of the species into southern Vigo County around 1990.

The lack of mosquitofish in northern Vigo County (Figure 1) as well as in Fountain, Parke, and Vermillion Counties in the upper Wabash drainage and Crawford, Martin, and Orange Counties in the Patoka and White River drainages indicates that this fish does not presently occur in these streams, where relatively little appropriate habitat exists.

Foods of *Gambusia*. The foods eaten by 320 individuals of *Gambusia affinis* from Posey County in and around Hovey Lake during the summer of 1967 are indicated in Table 1. The most common food item, in both percent volume and percent frequency, was the adult midge (Chironomidae), which formed 17.0% of the diet by volume and 14.6% by frequency, followed by algae (15.8% by volume and 13.0% by frequency) and the bryozoan, *Plumatella* (12.8% by volume and 10.7% by frequency). Chironomids in all 3 life forms made up 21.1% of the volume and occurred at a frequency of 18.7% in the mosquitofish from Hovey Lake. Only one mosquito, an adult, was found in the 320 stomachs.

At Reelfoot Lake in western Tennessee, Barnickol (1941) found that chironomid larvae made up 3.0% and culicid larvae less than 1.0% of the total food volume from the 318 mosquitofish stomachs he examined. Plant material comprised a higher volume (24.7%) than in this study (16.9%). Rice (1941), also at Reelfoot Lake, found that chrionomid larvae and pupae made up 2.0% and culicid larvae 13.0% of the total food volume in the stomachs of the 465 mosquitofish he examined. Rice also noted differences in both the total volume and frequency of food items in fish captured in open water as opposed to those taken in water with heavy vegetation. In the stomachs of *Gambusia* from open water, Chironomidae formed 12.0% of the food items by total volume and 13.2% by frequency. No Culicidae were found. For those mosquitofish taken from water with heavy vegetation, 25.0% of the total volume of food items eaten and over 28.0% of the food items by frequency were culicids. In this case, no chironomids were found.

Mosquitofish collected in our study were all taken in open water with the dominant vegetation being larger trees and shrubs. The effectiveness of *Gambusia affinis* in controlling mosquitoes, at least in relatively open water, is questionable at best. Perhaps a better common name for this fish would be "midgefish."

The foods in the stomachs of 36 blackstripe topminnows, *Fundulus notatus*, taken from central Indiana prior to the presence of *Gambusia affinis* are listed in Table 1. The main food items were chrionomid adults (35.6% by volume and 20.8% by frequency) followed by Formicidae (8.8% by volume and 6.9% by frequency) and damselfly (6.1% by volume and 4.1% by frequency). Chironomids in all 3 life forms comprised 39.9% of the stomach contents by total volume and 27.5% by frequency. Of the 27 food items identified from *Fundulus notatus*, 15 were food items and 3 were major food items (i.e., they formed at least 5% of the total food volume) used by *Gambusia affinis*.

Comparison of the foods in the stomachs of 56 topminnows from Vigo, Sullivan, Knox, and Pike Counties with foods in the stomachs of 47 mosquitofish taken in those same areas at the same time yielded twelve identifiable food items common to both species (Table 2). For each species, the food consumed in greatest quantity was the adult midge (12.8% by volume and 8.0% by frequency for mosquitofish; 14.3% by volume and 9.3% by frequency for topminnows).

Table 1. The principle food items found in the stomachs of 320 mosquitofish, *Gambusia affinis,* from Posey County, Indiana (listed in order of importance); and the food items found in the stomachs of 36 topminnows, *Fundulus notatus,* from central Indiana taken prior to the occurrence of mosquitofish there (not listed in order of importance).

Food	*Gambusia*		*Fundulus*	
	% Vol	% Freq	% Vol	% Freq
Chironomidae (adult)	17.0	14.6	35.6	20.8
Algae	15.8	13.0	0.4	1.4
Bryozoa (mostly *Plumatella*)	12.8	10.7		
Diptera (unidentified)	5.9	7.0	4.7	5.6
Cecidomyidae	4.4	5.8	0.1	1.4
Cicadellidae	4.3	3.9	2.4	4.1
Formicidae	3.7	4.3	8.8	6.9
Cladocera	3.4	2.9		
Chironomidae (pupae)	3.1	3.1	3.9	5.6
Cynipoidea	2.0	2.9		
Corixidae	1.9	1.9	2.8	1.4
Invertebrate (unidentified)	1.7	1.7		
Tipulidae (adult)	1.6	1.2		
Trichoptera (larvae)	1.6	1.7	2.2	2.8
Staphylinidae	1.6	1.4		
Araneae	1.4	1.4	2.2	2.8
Insect (unidentified)	1.3	2.3	2.8	1.4
Aphididae	1.1	1.4	2.5	4.2
Chironomidae (larvae)	1.0	1.0	0.4	1.4
Homoptera	1.0	0.8		
Gambusia (embryo)	1.0	0.8		
Sciomyzidae	0.9	0.6		
Plant (unidentified)	0.9	0.6		
Crustacea	0.9	0.8		
Ephemeroptera (naiad)	0.8	0.6		
Coleoptera (unidentified)	0.7	1.0	1.7	4.2
Saldidae	0.6	0.2		
Hemiptera	0.6	0.6		
Cercopidae	0.5	0.4		
Diptera (larvae)	0.5	0.8		
Syrphidae	0.4	0.4		
Lepidoptera (adult)	0.4	0.4		
Sciaridae	0.4	1.2		
Chrysochloridae	0.3	0.8		
Hymenoptera	0.3	0.8		
Gerridae	0.3	0.2		
Phoridae	0.3	0.2		
Geometridae	0.3	0.2		
Mycetophilidae	0.3	0.2		

Food	*Gambusia* % Vol	*Gambusia* % Freq	*Fundulus* % Vol	*Fundulus* % Freq
Simuliidae	0.3	0.2		
Acarina	0.3	1.0		
Lygaeidae	0.3	0.2		
Eriosomatidae	0.3	0.6		
Otitidae	0.3	0.4		
Carabidae (larvae)	0.3	0.2		
Carex (seed)	0.2	0.2		
Collembola	0.2	0.4	0.7	2.8
Culcidae (adult)	0.2	0.4		
Zygoptera			6.1	4.1
Grass seeds			3.8	5.6
Small fish			3.1	2.8
Ceratopogonidae			2.8	1.4
Hemerobiidae			2.8	1.4
Chermidae			2.8	1.4
Thysanoptera			2.2	6.9
Corrodentia			1.3	4.2
Daphnia			1.4	1.4
Ephemeroptera			1.4	1.4
Reduviidae			1.1	1.4
Coccidae			0.3	1.4
Totals	99.2*		100.0	

* Seven additional food items account for remaining 0.8% of *Gambusia*'s total food volume.

Chironomid adults, Corixidae, chironomid pupae, Cicadellidae, Diptera, Aphididae, Cecidomyidae, *Daphnia,* chironomid larvae, snails, Cynipoidea, and Coleoptera made up 85.5% of the total volume in mosquitofish and 70.5% in topminnows. The percent frequency of these food items was 53.4% in mosquitofish and 45.8% in topminnows. The foods consumed by the 2 species are quite similar. No mosquitoes (adult, pupae, or larvae) were found in the stomachs of either species.

Eleven food items that occurred at rates of at least 5% by volume in any of the groups of fish (*Gambusia* in Posey County, *Fundulus* from central Indiana before the arrival of *Gambusia,* and *Gambusia* and *Fundulus* when the two occurred together in central Indiana) were examined for statistical differences in food preference between fish groups (Table 3). Five of the food items (chironomid pupae, Cicadellidae, Diptera, Cecidomyidae, and Formicidae) showed no significant differences between any of the fish groups. Significant differences in rates of consumption occurred for the other six foods.

Two of the six, algae and bryozoans, were most heavily eaten by *Gambusia* in Posey County. These two foods may have been readily available in Posey County. Two other food items, chironomid adults and zygopterans, were most abundant in the stomachs of *Fundulus,* when that species occurred in the absence of *Gambusia* in central Indiana. Many of these specimens were from Vermillion

Table 2. A comparison of the food items taken from the stomachs of 47 individuals of *Gambusia affinis* and 56 individuals of *Fundulus notatus* in the area where their ranges overlap.

Food	*Gambusia*		*Fundulus*	
	% Vol	% Freq	% Vol	% Freq
Chironomidae (adult)	12.8	8.0	14.3	9.3
Corixidae	12.8	6.8	19.6	5.6
Chironomidae (pupae)	9.8	5.7	7.0	8.6
Invertebrate (unidentified)	8.5	4.6	0.9	1.4
Cicadellidae	8.2	4.6	7.9	2.3
Diptera (unidentified)	6.8	5.7	4.8	2.3
Aphididae	6.7	4.6	2.3	2.3
Cecidomyidae	5.5	3.4	1.4	1.9
Daphnia	4.0	2.3	3.7	7.1
Insect (unidentified)	3.1	3.4	0.3	0.5
Chironomidae (larvae)	3.0	1.1	0.7	0.9
Copepoda	2.3	1.1		
Mollusca (snail)	2.1	1.1	3.2	0.9
Cynipoidea	2.1	1.1	1.8	0.9
Delphacidae	2.1	1.1		
Phalacridae	2.1	1.1		
Plant (unidentified)	2.1	1.1		
Bryozoa (mostly *Plumatella*)	1.8	1.1		
Seeds (unidentified)	1.3	1.1		
Acarina	1.2	2.3		
Phoridae	1.1	1.1		
Coleoptera (unidentified)	0.4	1.1	2.6	1.9
Crustacea	0.1	1.1		
Tipulidae			3.9	1.4
Cercopidae			3.2	1.4
Staphylinidae			3.0	1.4
Chrysomelidae			2.8	1.9
Algae			2.5	0.9
Gerridae			2.5	0.9
Ephemeroptera (naiad)			1.8	0.9
Ceratopogonidae			1.8	0.5
Ephemeroptera			1.8	0.5
Coccidae			1.8	0.5
Miridae			1.8	0.5
Trichoptera (larvae)			1.6	1.9
Thysanoptera			0.5	1.4
Formicidae			0.4	0.9
Homoptera			0.4	0.9
Totals	99.9		100.3	

Table 3. The correlation between major foods (those occurring at a rate of 5% or more by volume in at least one sample) found in the stomachs of *Fundulus* and *Gambusia*. Food items in boldface occurred at significantly higher rates than other food items.

Food	*Gambusia* alone	*Gambusia* w/*Fundulus*	*Fundulus* w/*Gambusia*	*Fundulus* alone	*F* Value
Chironomidae (adult)	17.0	12.8	14.3	**35.6**	**4.817**
Corixidae	1.9	**12.8**	**19.6**	2.8	**24.755**
Chironomidae (pupae)	3.1	9.8	7.0	3.9	2.619
Cicadellidae	4.3	8.2	7.9	2.4	1.594
Diptera (unidentified)	5.9	6.8	4.8	4.7	0.085
Aphididae	1.1	**6.7**	2.3	2.5	**8.611**
Cecidomyidae	4.4	5.5	1.4	0.4	1.378
Formicidae	3.7	0.0	0.4	8.8	3.309
Zygoptera	0.0	0.0	0.0	**6.1**	**11.584**
Algae	**15.8**	0.0	2.5	0.4	**11.605**
Bryozoa (mostly *Plumatella*)	**12.8**	1.8	0.0	0.0	**1.873**
TOTALS	70.0	64.4	60.2	67.6	

County, north of *Gambusia*'s range and habitat. The zygopterans may have been particularly abundant there.

The most important food of both species, adult chironomids, was common in all samples but was significantly more abundant only in the sample where *Fundulus* occurred alone. Adult chironomid usage was not significantly different between any of the other three groups. Usage was second highest (17.0%) in *Gambusia* in Posey County and lowest (12.8% and 14.3%) when both fish species occurred together.

Since adult midges were the most abundant food eaten by both species, the two species of fish might compete for chironomids, if these insects were in short supply. Water boatmen (Corixidae) were taken at low rates by *Gambusia* in Posey County and by *Fundulus* before invasion by *Gambusia*. Water boatmen were eaten in significantly greater amounts where the two fish occurred together in central Indiana. The water boatmen might have been selected due to a shortage of midges. In addition, *Gambusia* fed on significantly more aphids when *Fundulus* was present.

ACKNOWLEDGMENTS

The authors wish to extend a special thanks to Thomas H. Cervone of Lochmueller & Associates, Evansville, and to Thomas P. Simon of the EPA, Chicago, for assistance and information, and to Felicia Lindley for running the statistical analyses.

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Printed on Recycled Paper

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